



4^o Enc.

7^e (20,2

4^o Enc.

7^e (20,2

Smellie. doctrines of Linnæus.¹ The substance of it was incorporated in his *Philosophy of Natural History*; and his opinions were then controverted by Dr. Rotheram, afterwards professor of natural philosophy at St. Andrews. Of his proficiency in these studies we find a more conspicuous proof. While he was attending the botanical class, the professor sprained his leg so severely that for a considerable interval he was unable to meet his students; and on this occasion he selected Smellie to continue the course of lectures. In a botanic garden, lectures cannot be servilely read from papers, either written by the lecturer himself, or supplied by others.

On the 25th of March 1765 he commenced business as a printer, in conjunction with two brothers named Robert and William Auld, the former of whom was a solicitor. His private resources were obviously scanty; and two of his friends, Dr. Robertson, professor of oriental languages, and Dr. Hope, professor of botany, advanced to him the sum of seventy pounds, which we reckon equivalent to two hundred in our present currency. This copartnery was dissolved within the space of less than two years, by the retirement of Robert Auld; but a new company, consisting of Balfour, W. Auld, and Smellie, commenced business on the 22d of December 1766. John Balfour, who was likewise a bookseller, had been a partner in the house of Hamilton, Balfour, and Neill. The new house published the *Journal*, a newspaper supposed to have been unprofitable. Their connexion only continued till the month of November 1771; and the modified firm of Balfour and Smellie continued the business from the twelfth of that month. Beside his share of the profits, the junior partner was to receive ninety pounds a-year, and he was bound to conduct the entire business of the office. His average income amounted to about L.200. After an interval of more than two years, he easily obtained from Lord Kames the favour of his becoming surety to the Royal Bank for a cash-account to the extent of two or three hundred pounds. Their acquaintance had arisen from a series of anonymous strictures which he communicated to his lordship when the *Elements of Criticism* were passing through the press of Murray and Cochrane. The author requested the acquaintance of his nameless critic, and afterwards honoured him with various marks of his friendly attention. He incidentally mentions his supping with Lord Kames, in company with Hume and other guests. He was likewise a guest at the learned suppers of Lord Monboddo; and he reckoned Lord Hailes, as well as Lord Gardenstone, among the number of his friends and well-wishers.

Balfour and Smellie were appointed printers to the university. The chief advantage which attended this appointment was the profit of printing the dissertations written by candidates for medical degrees. Smellie likewise printed the theses written by candidates for admission to the Faculty of Advocates; and his knowledge of the Latin language was in both cases found very serviceable to the writers. He rendered material assistance to his friend Dr. Buchan, in the composition of a work which attained to very extensive popularity. This work, entitled "*Domestic Medicine, or, a Treatise on the Cure and Prevention of Diseases*," was published at Edinburgh in the year 1770. In the course of forty years, it is said to have passed through twenty editions, each consisting of 6000 copies, besides many pirated editions in Ireland and America, and some even in Britain. Of this treatise, Smellie was sometimes represented as the sole author; but it appears with sufficient evidence that the manuscript was placed in his hands, and that in preparing it for the press, he made many essential alterations in its

form and style. It was so diffuse and redundant, that a single chapter, as originally written, would nearly have equalled the size of the entire book, as at first printed. These services were compensated with a bill for one hundred pounds.

Of Smellie's life, we have now arrived at an era which recommends him to the more particular regard of the writers and readers of the present work. The first edition of the *Encyclopædia Britannica* consisted of only three volumes, which began to be printed in the year 1771. The principal articles were written, compiled, or devised by him, and he prepared and superintended the entire publication. "As you have informed me," says a letter of Andrew Bell, the chief proprietor, "that there are fifteen capital sciences which you will undertake for, and write up the subdivisions and detached parts, conform[ably] to your plan, and likewise to prepare the whole work for the press, &c. &c., we hereby agree to allow you L.200 for your trouble." If his capital sciences had not exceeded the old number of seven, this remuneration could scarcely have been considered as extravagant. One of his original articles, contributed to this edition, was that on *Æther*, which attracted a considerable degree of attention, and gave no small offence to Dr. Cullen, whose theory was there exposed, though without any mention of his name. From internal evidence, he was convinced that the article must have been written by his colleague Dr. John Gregory. He at length ascertained the real author; and this discovery, says the late Dr. Gregory, "gave occasion to the complete alteration and softening of the article *Æther* in the second and all the subsequent editions of the *Encyclopædia*; so that nothing of it was allowed to remain that could give offence to Dr. Cullen."²

Of the second edition of this work Smellie was offered a share, apparently a third, conjoined with the charge of editorship. This offer he unfortunately declined, and thus lost the only golden opportunity that fortune ever presented to him. "At the death of Mr. Macfarquhar, printer, in April 1793, the whole work became the property of Mr. Bell. It is well known that Mr. Macfarquhar left a handsome fortune to his family, all or mostly derived from the profits of the *Encyclopædia*; and that Mr. Bell died in great affluence, besides possessing the entire property of that vast work; every shilling of which may be fairly stated as having grown from the labours of Mr. Smellie in the original fabrication of the work, which is confessedly superior, and all of which he and his family might have shared in equally with Mr. Bell and the other proprietor, if he had not been too fastidious in his notions, and perhaps too timid in his views of the risk which might have been incurred in the mercantile part of the speculation."³ His chief objection is stated, not with much probability, to have arisen from a difference of opinion as to the general plan: "because the other persons concerned, it has been said upon the suggestion of a very distinguished nobleman of the highest rank and most princely fortune, insisted upon the introduction of a system of general biography; which Mr. Smellie objected to, as by no means consistent with the title." If this statement is accurate, we consider the nobleman as decidedly right, and Smellie as decidedly wrong; inasmuch as the historical and biographical part of the work has recommended it to many readers, who do not feel an equal degree of interest in the arts and sciences. The perfection of such a work is to render it agreeable as well as instructive to the greatest possible number of readers. The second edition, consisting of 1500 copies, began to be published in 1776. The third, extending to no fewer than 10,000 copies of eighteen vo-

¹ Smellie's *Philosophy of Natural History*, vol. i. p. 245.

² Gregory's *Additional Memorial to the Managers of the Royal Infirmary*, p. 188.

³ Kerr's *Memoirs of the Life, Writings, and Correspondence of William Smellie, F.R.S. & F.A.S.*, vol. i. p. 363. Edinb. 1811, 2 vols. 8vo.



Smellie. lumes, commenced in 1786. By this edition, we are informed, the two proprietors "are said to have cleared a net profit of L.42,000, besides being each paid for their respective work in the conduct of the publication as tradesmen; Mr. Bell as engraver of all the plates, and Mr. Macfarquhar as sole printer."

Smellie afterwards embarked in a speculation which did not prove so lucrative. This was "The Edinburgh Magazine and Review," of which the first number appeared in the month of October 1773. The editor was Dr. Stuart, whose temper and discretion were not equal to his talents and learning. Smellie was one of five partners, including the editor; and besides printing the work at the ordinary rates, he "was regularly to compile the last half-sheet of every number, to consist of foreign and domestic occurrences, or the news-department, and other articles; to keep the accounts of the concern; to answer all letters relative to the concern; and to review certain articles, as should be agreed upon between him and Dr. Stuart." The work only extended to five volumes, closing with the number for August 1776. It was conducted with so much ability, that it might have run a more prosperous career, if the personalities of the editor, displayed within so narrow a field, had not excited a degree of hostility with which it was hopeless to contend. But the history of this work will be resumed in our notice of Gilbert Stuart.

Of the Society of Antiquaries, instituted at Edinburgh in 1780, Smellie was an original member. In 1781 he was elected Superintendent of the Museum of Natural History, which they proposed adding to their antiquarian cabinet. He afterwards published an "Account of the Institution and Progress of the Society of the Antiquaries of Scotland." Edinb. 1782, 4to. To this account he added a second part in 1784. He was elected to the office of secretary in 1793. This new institution excited the jealousy of some other learned bodies. The senate of the university presented a memorial to the lord advocate, remonstrating against the grant of a royal charter to the Society of Antiquaries, on the allegation that Scotland was too limited a country for two literary Societies; and proposing, that instead of granting such a charter, the king should incorporate a society under the designation of the Royal Society of Scotland. They further suggested "that the Society of Antiquaries would intercept the communication of many specimens and objects of natural history, which would otherwise be deposited in the museum of the university, and of many documents tending to illustrate the history, antiquities, and laws of Scotland, from being deposited in the library of the Faculty of Advocates. They likewise noticed that the possession of a museum of natural history might enable and induce the Society of Antiquaries to institute a lectureship of natural history, in opposition to the professorship in the university." Nor did the curators of the Advocates Library remain inactive. They represented to the lord advocate that the grant of a charter to the Antiquaries "might prove injurious to that magnificent library, by intercepting ancient manuscripts and monuments illustrative of the history and antiquities of Scotland, which would be more useful when collected into one repository than in a state of division." To all these representations the Society returned an elaborate answer, in the form of a memorial addressed to the lord advocate; and the royal charter was finally ratified in the month of May 1783. It is scarcely necessary to add, that few or none of the multifarious evils which had thus been predicted, were found to result from the incorporation of this Society, which has proved almost as harmless as any institution in the kingdom. The Royal Society of Edinburgh soon afterwards obtained its charter; and as a member of the Philosophical Society, Smellie was incorporated on the 23d of June 1783.

At the request of the Society of Antiquaries, he had in 1781 digested the plan of a statistical account of all the parishes of Scotland. The circulation of this plan did not excite much industry; but, at no distant period, it was followed by an extensive and important work. As superintendent of the museum, he was authorized to deliver in their hall a course of lectures on natural history. "His object was to deliver lectures on the philosophy of natural history, which is a subject totally different from what a public professor is obliged to teach. A professor must instruct his students in the technical and elementary part of the science; but the private lecturer was to confine himself to general views of the economy of nature."¹ The professor of natural history, who certainly had reason to fear such a rival, was alarmed at what he considered as an encroachment on his province, and this plan of lectures was reluctantly abandoned. On the death of Dr. Ramsay in the year 1775, Smellie had offered himself as a candidate for the professorship; but his claims were disregarded, and it was bestowed upon Dr. Walker, at that time minister of Moffat, and afterwards of Colinton.

Smellie however continued to prosecute his favourite study, and he published "Natural History, general and particular, by the Count de Buffon: translated into English. Illustrated with above 200 copper-plates, and occasional notes and observations by the Translator." Edinb. 1781, 8 vols. 8vo. "Much the greater portion of this extensive work," says Mr. Kerr, "was executed in a small correcting room or closet connected with his printing-office, where he was continually liable to interruption, from the introduction of proof-sheets for correction, and revises for comparison, and to the almost perpetual calls of customers, authors, and idle acquaintances: yet such was his accuracy of self-possession, that, as usual with almost every thing he wrote, he gave it out page by page, as fast as written, to his compositors, and hardly ever found it necessary to alter a single word after the types were set up from his first uncorrected manuscript. Although, to have enabled him to execute this translation in the excellent manner in which it is done, Mr. Smellie must necessarily have possessed a very thorough knowledge of the French language, it appears that he had acquired this entirely by means of his own private study, and without the assistance of any teacher; for we have been assured by those who knew him very intimately, that he was quite unacquainted with the pronunciation of French." A second edition of his translation, in nine volumes, followed in the year 1785. Other three editions, all of them extensive, were afterwards published; so that the work may be considered as having been eminently successful. The translator's notes were allowed to have added no inconsiderable value to the text; and the chief fault imputed to him was the use of provincial idioms. He was honoured with the correspondence of Buffon, and likewise of Pennant.

The firm of Balfour and Smellie having been dissolved, that of Creech and Smellie began business on the 14th of September 1782, and continued it till the close of the year 1789. Creech, well-known as a bookseller, was in all cases difficult to bring to a settlement of accounts, when he had any reason to believe the balance to be on the wrong side. The affairs of this copartnery, being somewhat intricate, were submitted to arbitration, and a balance was ultimately found due to Smellie; but the decision was so long deferred, that it was not pronounced till some time after his death. After the termination of these different partnerships, he continued the business on his own account. Lord Kames died in the year 1782; and he was now indebted to the kindness of Lord Gardenstone, who became his surety to the banking-house of Sir W. Forbes and Co.

¹ Smellie's Account of the Society of Antiquaries, part ii. p. 24.

Smellie. His next publication was "An Address to the People of Scotland, on the Nature, Powers, and Privileges of Juries. By a Jurymen." Edinb. 1784, 8vo. This tract is entitled to particular notice, because it contains a clear and judicious exposition of legal principles, very important in themselves, and at that period very little understood. "It is," he remarks, "a common notion that jurymen are judges of the *fact* only, and not of the *law*. This absurd, and often fatal prejudice is much more prevalent than might be expected, in a city like this, where general knowledge ought to be pretty widely diffused. It has perhaps been too much fostered by the injunctions of judges and magistrates. It is exceedingly natural that plain simple jurymen should look up with veneration to the high rank, and superior abilities of those men who are appointed by their sovereign to dispense justice over the nation. For this reason it is, that the English judges are so extremely solicitous not to inculcate their own opinions on the minds of jurymen, but to leave their determinations solely to the dictates of their own consciences. But from whatever source this prejudice may have derived its origin, I shall endeavour to shew that it has neither law nor common sense for its support." A further specimen may very satisfactorily be produced. "I know it to be the opinion of many jurymen, that after the court admits a *relevancy*, they are bound by their oaths to find the libel either *proved* or *not proved*. But these gentlemen should consider, that their business is to give a verdict of a very different kind. They are to judge both of the criminality of the culprit, and of his exculpatory evidence. The words *proved* or *not proved* should be for ever banished from the verdicts of juries. A relevancy may be found, when the jurymen, who hear the indictment impugned, are of an opposite opinion from the court. A crime may be libelled, when the facts related in the indictment, though completely proved, do not constitute the essence of the crime charged. Hence, whenever the minds of jurymen are convinced that a relevancy has been improperly found, their verdict, however the proof may stand, should be *Not guilty*. Indeed, the expressions, *Guilty* or *Not guilty* ought alone to be employed in verdicts." This tract excited a considerable degree of attention; and it was quoted with much approbation by Lord Erskine, in his famous speech in defence of Dr. Shipley, dean of St. Asaph. He published several other pamphlets, which chiefly related to local politics.

But the most elaborate of his works is "The Philosophy of Natural History." Edinb. 1790, 4to. This is an ingenious book, written in a very pleasing style, and it accordingly experienced a favourable reception. It was reprinted at Dublin and Philadelphia. Lichtenstein published a German translation, to which some notes were added by C. A. W. Zimmermann. For the original volume, Charles Elliot agreed to pay one thousand guineas, at six, twelve, and eighteen months, as well as a certain sum for every edition after the first. This enterprising bookseller died before the work was ready for publication; but the agreement was honourably fulfilled by his trustees, though the benefit accrued, not to the author himself, but to his family. "This," says Mr. Kerr, "was probably the largest sum that had ever been given, at least in Edinburgh, for the literary property of a single quarto volume, and evinced both the liberality of the bookseller, and the high estimation in which he very justly held the fame and talents of the author."

His plan however was not yet completed, and he immediately applied himself to the preparation of a second volume. He lived to bring it to a conclusion, though not to make any arrangement for its publication. During the last years of his life, his health appears to have been infirm and precarious. In June 1793, he stated to his friend Dr. Hutton, that he had for several months been distressed with a debility in his limbs, accompanied with a want of appetite; and to another medical friend, Dr. Gardiner, we find him stat-

ing very unfavourable symptoms in the course of the following year. After a long illness, he died on the 24th of June 1795, at the age of sixty-five. He left a widow, with four sons and four daughters; two sons and three daughters having died before their father. His eldest daughter was married to Mr. George Watson, an eminent portrait-painter in Edinburgh. Smellie had never been in affluent circumstances, but he left to his family the means of prosperity; and the printing business has been more successfully conducted by his son Mr. Alexander Smellie.

Of his Philosophy of Natural History, the second volume was published by this son in the year 1799. Another posthumous work speedily followed: "Literary and characteristic Lives of John Gregory, M.D., Henry Home, Lord Kames, David Hume, Esq., and Adam Smith, LL.D. To which are added a Dissertation on Public Spirit, and three Essays." Edinb. 1800, 8vo. His original plan comprehended the lives of other twenty-five men of literary eminence, with whom he was personally acquainted. One of these was his friend Dr. Stuart, with whose private history he was sufficiently familiar, and of which he could have supplied very curious, though perhaps not very edifying details. It is not however a subject of much regret that his plan was never completed. In the specimen with which we have thus been presented, there is too little biography, and too much discussion. This remark is more particularly applicable to the life of Dr. Gregory, which extends to 118 pages, but is almost entirely occupied with an account, not of the writer, but of his writings. The other lives are of less extent. In his account of Hume, he relates, without any symptom of disapprobation, the indecent levity with which he sported on the verge of another world; and in the same manner he likewise repeats the declaration of Dr. Smith as to the character of that philosopher, "I have always considered him, both in his lifetime and since his death, as approaching as nearly to the idea of a perfectly wise and virtuous man, as perhaps the nature of human frailty will permit." This ingenious printer may himself have been somewhat too anxious to be classed among philosophers.

Smellie appears to have been a man of excellent talents, and of extensive knowledge. His disposition was social, his habits were convivial, and he was distinguished by a sarcastic vein of wit and humour. According to the description of his biographer, he "was about the middle size, and had been in his youth well-looking and active; but when rather past the middle of life, he had acquired from almost constantly stooping at his desk to write or correct, a rather lounging gait and appearance; and from a long-continued series of difficulties in his affairs, and much disappointment in matters of affectionate moment, he had become careless and rather slovenly in his dress and appearance; wearing his hair long and bushy, his ordinary black and wide-made clothes ill brushed, and well sprinkled with snuff, and his usual old-fashioned cocked hat for the most part rusty." Burns describes him as "a man positively of the first abilities and greatest strength of mind, as well as one of the best hearts and keenest wits, that he had ever met with." And in the following lines, which allude to a club called the Crochallan Fencibles, he has exhibited a graphic delineation of Smellie:

To Crochallan came

The old cock'd hat, the brown surtout the same;
His bristling beard just rising in its might,
'Twas four long days and nights to shaving-night;
His uncomb'd grizzly locks, wild staring, thatch'd
A head for thought profound and clear unmatch'd;
And though his caustic wit was biting, rude,
His heart was warm, benevolent, and good. (x.)

SMELLING is the act by which we perceive smells, or become sensible of the presence of odorous bodies. The

Smelling.

Smelling. sensations of smell are excited by certain effluvia, which, in the open air, are always issuing from the surfaces of most bodies, and striking on the extremities of the olfactory nerves, give them a peculiar sort of impression, which is communicated to the brain. The particles which issue thus from bodies are extremely volatile, and produce sensation by a degree of contact, which, though insensible, is still more efficient than if it were more gross and palpable. It is by a similar species of insensible contact that the eyes and ears are affected by external objects; while, in the excitation of the sensations of touch and of taste, an actual and sensible contact of the object with the organ is necessary. The organs of smelling are the nostrils and olfactory nerves; the minute ramifications of the latter being distributed throughout the whole concavity of the former.

The effluvia from odorous bodies are constantly floating about in the atmosphere, and must of course be drawn into the nostrils along with the air in inspiration; "so that there is," as Dr. Smith observes, "a manifest appearance of design in placing the organ of smell in the inside of that canal through which the air is continually passing in inspiration and expiration." It has been affirmed by Boerhaave, that the matter in animals, vegetables, fossils, and the like, which chiefly affects the sense of smelling, is that attenuated substance, inherent in their oily parts, called *spirits*; because, when this is taken away from the most fragrant bodies, what remains has scarcely any smell at all; but this, he says, if poured on the most inodorous bodies, gives them a fragrantcy.¹ We cannot however enter at present upon this inquiry.

The sense of smell has a close alliance with that of taste; and it seems probable from the proximity in the situation of their organs in all animals, that both are principally intended to guide them in the choice of their food; so that from this close connection, they are better enabled to choose what is good for them, and to reject what would be injurious. This is the opinion of Dr. Reid, as it was, in a very early period of the history of philosophy, that of Socrates and of Cicero.² Dr. Reid also remarks, that the sense of smell probably serves the same purpose in the natural state of man; but it is not always a sure guide for this purpose. The organs of smell differ, like those of the other senses, according to the destination of the animals to which they belong; and we know, that this sense is in man much less acute, than in many other animals. We see, that in the choice of their food, they are guided by the senses of smell and of taste, except when man has brought them into a sort of unnatural state by domestication. And this circumstance renders it probable, that both these senses were intended to serve the same purpose in the natural state of our species, although less calculated for this end than they were in the brutes, on account of the great superiority of their smelling organs. Besides, since it is probable that man, in the natural state, acts more by instinct than when civilized in society, so also it is reasonable to think, that he may possess some of the senses, this of smell for instance, in greater acuteness than we do. This indeed we are assured to be a fact; for we are told in the *Histoire des Antilles*, that

there are negroes who, by the smell alone, can distinguish the footsteps of a Frenchman from those of a negro. Smelling.

The sense of smell is much more obtuse in man than in some of the lower animals. Dogs we know possess a power of smelling, of which we can scarcely form a conception, and which it is happy for us we do not possess;³ and birds of prey are said to possess this sense in still greater acuteness. But although this be more perfect, still the sense of smelling in man, who has other means of judging of his food, is such as to fit him for deriving enjoyment from a diversity of scents, particularly those of flowers and perfumes, to which dogs and other animals seem perfectly insensible. It has been said, we are aware, that some animals, the elephant for instance, are capable of this enjoyment;⁴ but of this fact we cannot help being very doubtful.

There is a very great sympathy between the organs of smell and of taste; for any defect or disease of one is generally attended with some corresponding defect or disease of the other. There is also a greater similarity between the sensations of both these, than between those of any other two senses; and hence it is, that we can sometimes tell the taste of an object from its smell, and *vice versa*. Hence also the reason why we apply the same epithets to the names of both these classes of sensations; as a sweet smell or taste.

It deserves also to be remarked, that both these senses seem subservient to the preservation of the animal existence, rather than to any other purpose. They accordingly constitute an object of the natural history of man, rather than of intellectual or of moral philosophy. The other three senses, on the contrary, seem rather intended for, as they certainly are essential to, our intellectual improvement, and become, of course, a proper object of investigation in the sciences of moral philosophy, or metaphysics.

The advantages derived by man and the other animals from the sense of smelling are not confined to the assistance which it affords them in the choice of their food. Most bodies in nature, when exposed to the open air, are constantly sending forth emanations or effluvia of such extreme minuteness as to be perfectly invisible. These diffuse themselves through the air, and however noxious or salutary, would not be perceived without the sense of smelling, which, if not vitiated by unnatural habits, is not only a faithful monitor when danger is at hand, but conveys to us likewise the most exquisite pleasures. The fragrance of a rose, and of many other flowers, is not only pleasant, but gives a refreshing and delightful stimulus to the whole system, while the odours proceeding from hemlock, or any noxious vegetable, or other substance, are highly offensive to our nostrils. Hence we are naturally led to seek the one class of sensations, and to avoid the other.

In some species of animals the sense of smell seems to be connected with certain mental sympathies, as those of hearing and sight are in all that possess them in any high degree; for not only their sexual desires appear to be excited by means of it, but other instinctive passions, which, according to the usual system of nature, should be still more remote from its influence. Dogs, although wholly unac-

¹ See also Sir William Drummond's Academical Questions, book i. chap. 9.

² "Ut gustus," says a learned physiologist, "cibi itineri, sic olfactus ostio viarum, quas aer subire debet, custos præponitur, moniturus ne quid noxii, via quæ semper patet, in corpus admittatur. Porro, ut gustus, sic quoque olfactus ad salutarem cibum invitat, a noxio aut corrupto, putrido imprimis vel rancido, deterret."

"When thou seest the mouth, through which animals take in whatever they desire, always placed near the nose and eyes, thinkest thou not, says Socrates to Aristodemus, that this is the work of a providence." (Xenophon's Memorabilia, book i. chap. 4.)

³ "The excessive eagerness which dogs express on smelling their game, seems to be but little connected with the appetite for food, and wholly independent of any preconceived ideas of the objects of their pursuit being fit for it. Hence several kinds of them will not eat the game which they pursue with such wild impetuosity; and of which the scent seems to animate them to a degree of ecstasy far beyond what the desire of food can produce." (Knight on Taste.)

⁴ There is an animal to which, naturalists say, perfume is so agreeable and so necessary, that nature has provided it with a little bag stored with an exquisite odour. "On pretend," says Buffon, "que la mangouste ouvre cette poche, pour se rafraichir lorsqu'elle a trop chaud."

Smelling. acquainted with lions, will shudder at their roar; and an elephant that has never seen a tiger, will in the same manner show the strongest symptoms of horror and affright at the smell of it. "The late Lord Clive," says an ingenious writer, "exhibited a combat between two of these animals at Calcutta; but the scent of the tiger had such an effect upon the elephant, that nothing could either force or allure him to go along the road, where the cage in which the tiger was inclosed, had passed, until a gallon of arrack was given him. Upon this, his horror suddenly turning into fury, he broke down the paling to get at his enemy, and killed him without difficulty."

If riding along a road, near which a dead horse, or part of its carcass, happens to be lying, we know, that our horse although he sees it not, cannot be made to pass the place but with difficulty. Where blood has been shed, particularly that of their own species, oxen will assemble, and upon smelling it, roar and bellow, and show the most manifest signs of horror and distress; and yet these symptoms could not arise from any associated notions of danger or death, since they appear in such as never had any opportunities of acquiring them. They must therefore be instinctive like other instinctive antipathies and propensities. But although in their mutual intercourse, animals make much use of the sense of smell, still it does not seem to be further concerned in exciting their sexual desires, than in indicating their object.

Some of those splenetic philosophers, who are ready upon all occasions to quarrel with the constitution of nature, have taken the liberty of condemning their Maker, because it has pleased his unfathomable wisdom to bestow in some instances upon the brutes senses and instincts more perfect than he has given to man, without reflecting that he has given to man an ample equivalent; for it may be asked with the poet,

Is not his reason all these powers in one?
Is Heaven unkind to man and man alone?
Shall he alone, whom rational we call,
Be pleased with nothing if not blessed with all?

With respect to that unknown peculiarity of bodies, which is the cause of our sensations of smell, the opinions of philosophers have been very various. Until of late, the doctrine of Des Cartes and Locke on this subject was pretty generally received; but, since the publication of Dr. Reid's works, his opinion, which we deem the most correct and satisfactory, has become very popular. We will endeavour to abridge his account of this matter. For this purpose, let us suppose a person, who has grown up without the sense of smell, to be immediately endowed with the use of this organ, and placed near some flowers of an exquisite savour. When he examines what he feels in such a situation, he can find no resemblance between this new sensation, and any thing with which he is already acquainted. He finds himself unable to explain its nature, and cannot ascribe to it figure, extension, or any known property of matter. It is a simple affection, or feeling of mind, and, considered abstractedly, can have no necessary connection with the nerves, the nostrils, or effluvia, or with any thing material whatever. By the nature of his constitution he is however led to refer this peculiar sensation to the nostrils, as its organ; and when, from experience, and by means of touch, he learns that external objects have the power of exciting this sensation, he concludes, that there must exist in bodies some unknown cause by which it is excited. In the first part of this process he considers the feeling, or sensation, abstractedly. As such, it exists in the mind only; and cannot exist there but when the mind is conscious of it. His consciousness soon enables him to distinguish different sorts of smells, all of them very distinct from one another, but, conformably to the nature of all sensation, extremely simple. He concludes, that each of these must have a distinct cause; and finding, by experience, that this cause is an unknown something in bodies, he concludes, that it must be

a property of matter, and, for want of another, gives it the name of smell. When he removes an odorous body from the organ, the sensation vanishes; when the body is again applied, the sensation is excited; and hence it is, that he is led naturally to connect the sensation with this unknown peculiarity of bodies by which it is produced. But since we see, that the sensation is, in a great degree, related to other objects besides its unknown cause, to the mind in which it exists, for instance, and to the organ which is its instrument, it may be asked why it becomes associated in the mind with its cause only? The reason seems pretty obvious. No single sensation, or class of sensations, is more connected with the mind, than any other of which it is susceptible. Nor is the connection subsisting between the organ and any of the sensations peculiar to it, greater than that which subsists between it and every other sensation of which it is the inlet. Hence the connection between the smell of an orange and the mind, or between it and the nostrils, is very general, and cannot, in the former instance, distinguish it from any other sensation of whatever kind, nor, in the latter, from any other particular smell. But the connection between this sensation and the orange is peculiar and permanent; and we accordingly find them always associated in the mind, just as we associate the notion of fire with the sensation of burning. The relation which a sensation of smell, or any sensation, bears to the mind, to an organ, or to the memory and conception of itself, is common to all sensations. The relation which any sensation bears to its own cause, suppose of the sensation of smell to a particular virtue or quality of bodies, is common to it with every other sensation, when considered with respect to its peculiar cause. And finally, a sensation of any kind bears the same sort of relation to the memory and conception of itself, that any other feeling or operation of mind bears to the conception and memory of that particular feeling or operation.

Whatever then be the nature of the minute particles of bodies by which our sensations of smell are excited, we cannot help considering their unknown cause as a virtue or quality of matter. Like all other modifications of material substance, it must be confessed, that this can have no resemblance to the sensations of mind. But we are not therefore to conclude with the followers of Des Cartes and Locke, that this secondary quality is a mere sensation; especially as we can readily conceive it existing where it is not smelled, or even after supposing the annihilation of every sentient being throughout the universe. The existence of the sensation we know to be momentary and fugitive; but in the existence of its cause we can, without difficulty or inconsistency, conceive a permanency independent of mind and of its sensations.

The doctrine which we have been illustrating has of late been called in question by a sceptical writer, who, it appears to us, has upon this occasion been entirely deficient in his accustomed acuteness. Dr. Reid's speculations seem so full, so clear and convincing, that we are at a loss to conceive how his meaning can be misunderstood; and yet the argument and objections of the writer to whom we allude, derive all their plausibility from a misinterpretation of Dr. Reid's meaning, and from a deviation from the established use of language. "An eminent metaphysician," says this author, "has declared that he has not the least difficulty in conceiving the air perfumed with aromatic odours in the deserts of Arabia; and he has decided, that the man who maintains smells to exist only in the mind must be mad, or must abuse language and disgrace philosophy. There are some authors, nevertheless, who differ widely on this subject from the learned metaphysician. Is it possible for a sensation to exist where there is no sentient? The authors to whom I allude think it impossible." And so, we may tell this learned author, does Dr. Reid, if he will take his word for it. Of the sensation of smell he remarks, "It

Smelling. is indeed impossible, that it can be in any body ; it is a sensation, and a sensation can be in a sentient thing only."¹ Again, "I can think of the smell of a rose when I do not smell it ; and it is possible that when I think of it, there is no rose any where existing ; but, when I smell it, I am necessarily determined to believe that the sensation really exists. This is common to all sensations, that, as they cannot exist but in being perceived, so they cannot be perceived but they must exist."² But, continues this acute metaphysician, "a smell is nothing else than a sensation. It is a feeling, which may be agreeable or disagreeable ; which may, as some think, be excited by various combinations of elements ; but which, since it is a feeling, cannot be those elements which are said to cause it, and cannot exist where there is no creature to perceive it. What is to be understood, in philosophical strictness, by the perfumes of the desert ? We can excuse the poet when he makes the ocean smile,³ the winds dance,⁴ and the flowers respire ;⁵ or even were he to perfume the desert. But the philosopher is no such magician, and had better not wander through the regions of fancy in search of sensations where there is no sentient." And is it then true that the word smell means only a sensation ? A sensation is no more than an effect ; it is a transient modification of the mind, which the mind itself can never produce. It must then have some cause which is external to the mind. Now, it is to this cause, and not to the sensation, that the name smell is most frequently applied in all languages ; and it is this cause which Dr. Reid supposes capable of existing in the deserts of Arabia, where there is no sentient being to perceive it. But let us hear himself. "We have considered smell as signifying a sensation, feeling, or impression upon the mind ; and in this sense it can only be in a mind or sentient being ; but it is evident that mankind give the name of smell much more frequently to something which they conceive to be external, and to be a quality of body ; they understand by it something which does not at all infer a mind, and have not the least difficulty in conceiving the air perfumed with aromatic odours in the deserts of Arabia, or some uninhabited island where the human foot never trod."⁶ "The faculty of smelling is something very different from the actual sensation of smelling ; for the faculty may remain when we have no sensation. And the mind is no less different from the faculty, for it continues the same individual being when the faculty is lost. What is smell in the rose ? It is a quality or virtue of the rose, or of something proceeding from it, which we perceive by the sense of smelling ; and this is all we know of the matter. But what is smelling ? It is an act of the mind, but is never imagined to be a quality of the mind. Again, the sensation of smelling is conceived to infer necessarily a mind or sentient being ; but smell in the rose infers no such thing. We say, this body smells sweet, and that stinks ; but we do not say, this mind smells sweet, and that stinks ; therefore smell in the rose, and the sensation which it causes, are not conceived, even by the vulgar, to be things of the same kind, although they have the same name."⁷

There are some other remarks on Dr. Reid's opinion, in the work upon which we have been commenting, which we shall pass by ; we may however notice the author's concluding argument. After mentioning some examples, he observes, "Now, in these instances, we see men and animals, that must have perception of smell, if I may be permitted to say so, altogether different from each other. Is not smell sensation when the spaniel finds sport in the field for his master ; when the shark pursues through the ocean its expected victim ; and when the camel conducts the thirsty wanderer to a fountain of fresh water, across the burning sands of the Arabian desert ? If no animal had the

sensation of smell, there would be no odour ; for aroma and oils may be thought to be material compositions, but are neither agreeable nor disagreeable feelings." If men and animals differ in their perceptions of smell, and, no doubt, difference of organization will cause them to do so, the conclusion should not be, we think, that smell is merely sensation, but that there is actually something external which is the cause of their sensations, and about which they differ. A rose put to the nostrils of a man, and then to those of a dog, may excite very different sensations ; but we cannot think that the peculiarity of the rose, which excites those different sensations, varies by thus changing the position of the rose. If at table one person mistakes mutton for beef, and another thinks that it is venison, the conclusion may be, that it is neither venison nor beef ; but no man in his senses, can conclude that there is no meat at the table. But, "is not smell sensation when the spaniel finds sport in the field ? There is sensation no doubt ; but we may be permitted to ask, what would become of the spaniel's sensation of smell and of his master's sport, were there no game in the field ? What of the shark's sensation of smell and pursuit, were there no victim in the ocean ? and what of the camel and the thirsty wanderer, were there no fountain of fresh water in the Arabian desert ? "The smell of a rose signifies two things," says Dr. Reid ; "first, a sensation which can have no existence but when it is perceived, and can only be in a sentient being or mind ; secondly, it signifies some power, quality, or virtue in the rose, or in effluvia proceeding from it, which hath a permanent existence independent of the mind, and which, by the constitution of nature, produces the sensation in us. By the original constitution of our nature, we are both led to believe that there is a permanent cause of the sensation, and prompted to seek after it ; and experience determines us to place it in the rose. The names of all smells, tastes, sounds, as well as heat and cold, have a like ambiguity in all languages ; but it deserves our attention, that these names are but rarely, in common language, used to signify the sensations ; for the most part, they signify the external qualities which are indicated by the sensations."⁸ We have been induced thus to discuss this topic at some length, because we regretted to see Dr. Reid's opinion and reasoning misrepresented ; and we shall now conclude, not as this modern Berkeleyan does, "that if no animal had the sensation of smell, there would be no odour," but, that if there were no odour or external cause of smell, no animal would have this sensation.

SMEETING IRON by HOT-BLAST. Since the article on Recent the MANUFACTURE OF IRON was published in the usual order of the progress of this work, certain changes have been introduced in the process of making iron, of so extensive and important a character, that we cannot consider them in any other light than as effecting an entire revolution in those branches of industry and of commerce connected with the manufacture and application of that most valuable of metals. The change has been comparatively unnoticed, extending itself during the last ten years, from the little spot in a remote part of this island whence it took its origin, and has now found its way over a great part of the old world, and been adopted extensively in the new. Wherever it has found its way, wealth and prosperity have attended it, poverty and sterility have fled before it ; and there have been opened up vast stores of mineral wealth to assist in the advancement of civilization and industry, which our former impotence and want of skill had marked with the stigma of utter unproductiveness. It is therefore necessary that we give in this article, as supplementary to our former treatise, an account of the new process, now well known over the whole manufacturing world as the *hot-blast process* for smelting iron.

Smelting
by hot-
blast.

¹ Reid's Inquiry, ch. ii. sect. 2.

² Reid's Inquiry, chap. ii. sect. 3.

³ Milton.

⁴ Cowley.

⁵ Thomson.

⁶ Inquiry, chap. ii. sect. 8.

⁷ Inquiry, chap. ii. sect. 9.

⁸ Inquiry, ch. ii. sect. 9.

Smelting
by hot-
blast.

Inventor of
the new
process.
Nature of
the inven-
tion.

The hot-blast process was invented in Scotland by Mr. James Beaumont Neilson, a practical engineer at Glasgow, and was by him made the subject of a patent, dated September 1828, being entitled, an "improved application of air, to produce heat in fires, forges, and furnaces, where bellows and other blowing apparatus are required."

The invention of Mr. Neilson, like a great many other inventions, and indeed some of the most valuable, is characterized by extreme simplicity; and his invention so perfectly accords with all the known laws of physics, that we at once apply to it the well known exclamation of wonder, "how strange! that a thing so obvious should not have been done long before!" an exclamation in which we too often find ourselves doing an act of injustice to the very inventors to whom we lie under the weightiest obligations. Mr. Neilson's hot blast is as simple a contrivance as was the steam-engine condenser of his countryman, Mr. Watt, and indeed bears a very close analogy to its character as an invention. Before the time of Mr. Watt, steam was introduced into that part of the steam-engine where it performed its labour, and was then condensed into water in the same place where it had done its duty, thereby causing great waste of fuel and loss of power; and to remedy this defect, Watt introduced his new principle on which his fame rests; he used a *separate condenser*, that is, cooled the steam, and reconverted it into water, not in the cylinder, where it was detrimental, but in a separate vessel communicating with it. In like manner, Mr. Neilson's invention consists in separately heating that which was formerly done so as to be injurious to the process intended. Cold air was blown into a furnace designed to produce intense heat for the smelting of iron from ore, so that the cold blast of air itself required to be heated by the fuel in the furnace intended to smelt the iron, and so its temperature was cooled down by the very intensity of the blast required for the desired combustion. To remedy this defect, Mr. Neilson introduced his new principle of hot blast; and instead of allowing this blast of cold air to enter at once from the blowing machine or bellows into the furnace, to be heated there, he provided a *separate heating apparatus*, by which the air of the blast was to be heated by a separate furnace and fire, previously to its entrance into the smelting furnace. This is the whole invention. A hot blast of air, instead of a cold one, is thus introduced for the generation of heat. Could any thing be more simple, more natural, more appropriate, or more likely to prove effectual? This is the hot blast, which has already in this and other countries created many millions of valuable property out of what was formerly worthless, because unavailable by any of the processes formerly known.

Practical
introduc-
tion of the
hot-blast.

Like most other inventions, the progress of this was at first very slow. Retarded by practical difficulties, which beset all new processes in their first use, by men who have every thing to learn,—stopped every now and then by the prejudices of custom and ignorance, which cling with inveterate tenacity to maxims of established practice, and repel equally the innovations which improve and those which merely alter without improvement,—opposed also by the change of interests which such a revolution must necessarily involve; the invention, tardy in its first steps, and feeble in its early efforts, was more than once at the point of being altogether abandoned. Like the invention of Watt, a great part of the interest in its possible remuneration was transferred by the inventor to strangers, whose combined efforts and influence it was necessary to obtain on the side of the innovation. To Mr. Dunlop of Clyde iron-works Mr. Neilson had to give up three-tenths of his patent rights; to Mr. Mackintosh three-tenths; and one-tenth to Mr. Wilson of Dundivan, retaining to himself only three-tenths of this valuable monopoly. But the transfer was judicious; it was necessary. Mr. Mackintosh is distinguished as a man of much practical science; Mr. Dunlop was one of the most sagacious iron masters of his

time; and Mr. Wilson was a man of tried practical talent. The co-operation of these gentlemen was essential to the speedy and successful trial of the novel though simple process.

The following is the specification of Mr. Neilson's patent: "I, James Beaumont Neilson, do hereby declare, that the nature of my said invention for the improved application of air to produce heat in fires, forges, and furnaces, where bellows or other blowing apparatus are required, and the manner in which the same is to be performed are particularly described and ascertained as follows: That is to say, a blast or current of air must be produced by bellows or other blowing apparatus in the ordinary way, to which mode of producing the blast or current of air this patent is not intended to extend. The blast or current of air so produced is to be passed *from the bellows or blowing apparatus into an air vessel or receptacle, made sufficiently strong to endure the blast, and through and from that vessel or receptacle, by means of a tube, pipe, or aperture into the fire, forge, or furnace.* The air vessel or receptacle must be air-tight, or nearly so, except the apertures for the admission and emission of the air; and at the commencement, and during the continuance of the blast, it must be kept *artificially heated to a considerable temperature.*

"It is better that the temperature be kept to a red heat, or nearly so; but so high a temperature is not absolutely necessary to produce a beneficial effect. The air-vessel or receptacle may be conveniently made of iron; but as the effect does not depend upon the nature of the material, other metals or convenient materials may be used. The size of the air vessel must depend upon the blast, and on the heat necessary to be produced. For an ordinary smith's fire or forge, an air vessel or receptacle, capable of containing 1200 cubic inches, will be of proper dimensions; and for a cupola of the usual size for cast-iron founders, an air-vessel capable of containing 10,000 cubic inches will be of a proper size. For fires, forges, or furnaces, upon a greater scale, such as blast-furnaces for smelting iron, and large cast-iron founders' cupolas, air-vessels of proportionably increased dimensions and numbers are to be employed. The form or shape of the vessel or receptacle is immaterial to the effect, and may be adapted to the local circumstances or situation. The air-vessel may generally be conveniently heated by a fire, distinct from the fire to be affected by the blast or current of air, and generally it will be better that the air-vessels and the fire by which it is heated should be inclosed in brick-work or masonry, through which the pipes or tubes connected with the air-vessel should pass. The manner of applying the heat to the air-vessel is, however, immaterial to the effect if it be kept at a proper temperature. In witness whereof, I, the said James Beaumont Neilson, have hereunto set my hand and seal, the 28th day of February, in the year of our Lord 1829."

The only part of the process of smelting the iron which is at all affected by this novelty, is the transit of the air from the blowing machinery into the smelting furnace.

The bellows, steam-engine, water-wheel, blowing cylinders, equalizing reservoirs, or other apparatus of whatever sort, for producing the current of air to blow the fire, are left unchanged, as we have already described and figured them in our article on IRON. The furnace may be left of its former shape and dimensions in every respect as used in the old process, and as we formerly described them; all that is required for the introduction of the new process, is to interpose between the smelting furnace and the blowing machinery an oven, heated by a separate fire, through which, in appropriately shaped vessels or pipes, the blast of air on its way to the furnace may be heated to a considerable temperature,—400°, 600°, or any temperature found most suitable to the purpose, and so blown upon the incandescent fuel in the furnace in a hot blast, as distinguished from the ordinary cold blast of atmospheric air.

The consequences of this hot blast system in an econo-

Smelting
by hot-
blast.

Specifica-
tion of
the hot-
blast pa-
tent.

Manner of
using the
hot-blast.

Smelting
by hot-
blast.

Advan-
tages of the
hot-blast
system.

mic point of view, may be illustrated by the following experimental facts.

In a given furnace in Scotland, previous to the introduction of the new process, the following was the average result obtained:

20 tons of coal (coked),
with $3\frac{1}{2}$ tons of limestone,
smelted $4\frac{1}{2}$ tons of iron,
being $3\frac{1}{2}$ tons of fuel to each ton of iron.

In the same furnace, by the introduction of the new process, the result was as follows:

14 tons of coal (raw),
with $2\frac{1}{4}$ tons of lime,
smelted 8 tons of iron,
being $1\frac{3}{4}$ tons of fuel to each ton of iron.

Here, then, we see that, in the first place, one half of the fuel only is required; that coking, a very expensive process, is avoided, the coal being used raw, which was formerly impossible; and that only about one-third of the quantity of limestone is required to flux the iron, and all the cost of these materials, and all the labour employed in their transport, and in the process of melting, are clearly saved. But these were not the only benefits conferred on the iron-master. The same furnace, blowing apparatus, and establishment, that formerly produced fifty tons a-week, yielded under the hot blast more than double that quantity.

Peculiar
advantage
of the hot-
blast in
Scotland.

As it was in Scotland that these advantages were first obtained, so it is there that they are still possessed in the highest degree. Previously to the introduction of the hot blast, it had become an almost hopeless competition to produce iron there at so cheap a rate as the Welsh iron-masters could import it into Scotland. The hot blast at once turned the scale; and Scotland now transmits annually many thousand tons of iron to all the markets of England, and even into the very heart of the iron districts of the principality itself.

The cause of this difference between the advantage which Wales has derived from the hot-blast process, and that conferred on Scotland, is simply this: the coal fields of Wales are a rich, strong, and highly carbonaceous fuel, which loses not more than thirty to forty per cent. in the process of coking. The coal basin of Scotland in the iron district is, on the contrary, of a poor, earthy, light description, so as to lose from fifty to sixty per cent. in the process of coking, and giving, for every two tons of coal, not more, and frequently much less, than one ton of coked fuel fit for the cold-blast smelting-furnace. The expense and loss in the Scottish coal by this preparatory process of coking, was therefore excessive, when compared with the Welsh coal; and hence the adoption of this new plan, which did not require this preliminary process of coking, became a much greater boon to the Scotchman, in exact proportion to his former disadvantage.

Result in
Stafford-
shire.

Great as these advantages have been found in Scotland, they have by no means been limited to the country of the inventor. In Staffordshire, in the wonderfully rich mineral basins of Dudley, and in Derbyshire, the invention was very early introduced, and most successfully practised. The following are the general results of the hot-blast system, as now practised in Staffordshire, in comparison with the old system:

By the cold blast,
8 tons of coal (coked),
with $1\frac{1}{10}$ ton of lime,
yielded 3 tons of iron,
being $2\frac{2}{3}$ tons of fuel to each ton of iron.

By the hot blast, in 1840,
 $2\frac{1}{2}$ tons of coal (raw),
with $\frac{6}{10}$ ths of a ton of limestone,
yield $2\frac{1}{2}$ tons of iron,
being 1 ton of fuel to each ton of iron.

Hot-blast
admits the
use of in-
ferior ma-
terials.

The saving thus obtained in the article of fuel, is accompanied, it will be noticed, in every instance, with a corres-

ponding saving in the limestone employed to flux the metal. But even here the whole amount of advantage does not meet the eye. It was formerly important to use the very best quality of coal that could be obtained,—light, bituminous, or earthy coal, being least fit for the purpose, and most unprofitable. Now, although it is still desirable to have a better rather than a worse fuel, the importance of this point is so greatly diminished, that almost all the inferior descriptions of poorer and more bituminous coal may be employed with economy and advantage. Limestone of the best quality was essential to the produce of good iron by the old method; by the new method, it is obvious, from inspection of the examples given, that the saving in limestone varies from a third to two-thirds of the quantity employed; but, in addition to this, it has become practicable to employ limestone of a very inferior quality, where better may be scarce, without sensible deterioration of the metal.

For the production of good iron, the hot-blast system has thus opened vast resources, which formerly could not be rendered available, in consequence of the inferior quality of some one of the raw materials which could be brought together in a given locality. In one place, abundant in excellent carbonate of lime and rich ore, it became impossible to realise the mineral wealth, on account of the inferior quality of the coal; while, in another, an abundant supply of good limestone, and of good coal, could not be used with advantage, from the poverty of the ore, which happened to be a clay stone, containing a small proportion of iron. Perhaps, also, a portion of sulphur mixed with the materials in such a quantity, as to ruin the iron. These all are counterbalanced by the hot blast, and every one of these impracticable cases is now exemplified in daily use.

But there is no sphere in which the hot blast has exerted a more beneficial influence in promoting the success of industry, and extending the resources of civilization, than in its application to those sterile districts of the mineral world, known as the region of the stone coal, blind coal, or anthracite formation. In the blind or stone coal strata, we have that most valuable of all combustibles, carbon, in a condition of high density and purity, amounting to as much as ninety or ninety-five per cent. of the stone coal, with a very small per centage of earthy or hydrogenous matter, yet so contracted, and, as it were, iron-bound, so hard and obdurate, that, instead of forming a good combustible, it seems to partake of the nature of that wonderful and brilliant substance, so hard of combustion as to have been reckoned one of the incombustibles until the glass of the accomplished analyst resolved the glittering brilliant into its primitive carbon. The anthracite seems, in fact, truly to deserve the name of the "black diamond," having been rendered, by its dense and close structure, nearly as incombustible. Although America, and many wide districts of Europe, abound with this rich carbon, it has failed to furnish, even in the hands of many accomplished chemists and mechanics, an available fuel, either for the generation of steam, or for the ordinary wants of social life, and has resisted even the intense heat of the blast furnace. But even its consummate obstinacy has yielded to the power of the hot blast. In Wales, and in America, hot-blast iron of the very finest quality is now made from stone coal; and thus stores of the richest fuel which the world contains, appear only to have been reserved, by their wonderful obduracy, from the rapid destruction to which all other fuel has been so wastefully subjected, to supply the civilization and science of the nineteenth century with the means of rewarding and extending its astonishing discoveries. So kindly has Providence placed at the surface of the earth one mineral fuel to replace the forests which supplied the fires of our forefathers, and deposited another still richer, but more remote in the bowels of the earth, to await and to reward the industry and research of

Smelting
by hot-
blast.

Gives in-
creased
value to
the poorer
sorts of
fuel, flux,
and ore.

Allows
stone coal
to be em-
ployed with
advantage.

SMELTING.

Smelting by hot-blast. their children and our own. What geologist will henceforth call in question the abundance of that supply, which now seems to augment with the very means that are invented for increasing its consumption?

Value of the hot-blast in Welsh anthracite district, The Welsh coal-field is perhaps the richest in the world. Rich with bitumen on one side, it gradually falls off by insensible gradations into a more purely carbonaceous, but still free-burning coal, and, passing through every intermediate gradation, is found at last in the state of a rich, resplendent refractory anthracite, or stony coal. This, mixed in the proportion of two to three, three to two, or half and half, smelts iron readily under the hot blast, and produces a rich powerful pig, possessing the qualities of a rich charcoal iron, and also capable of being converted into a most tenacious and malleable bar iron. In the anthracite district of Wales, new furnaces are rapidly rising into use; and Mr. Crane is distinguished by his extensive use of Mr. Neilson's hot-blast in that application of it.

and in the anthracite district of America. But it is probably in America that the hot-blast system will most extensively contribute to the development of mineral wealth. The anthracite is there the staple of fuel. It covers a vast extent of country, and constitutes the only substitute with which our transatlantic brethren can replace those forests that are so rapidly receding before the advances of civilization. Here the hot-blast is most successfully employed.

Description of the hot-blast apparatus. We have thus given our readers the general specification of the hot-blast improvement; a specification so general as to include all possible forms of apparatus, applicable, not only to the smelting of iron, but to all cases of manufacture in which a blast is employed to produce heat, and which touches only the process of heating the air, without regard either to the mode of producing the blast, the mode of applying the blast, or the means of heating air; and the patent only provides for the carrying into effect the process of heating the air, that the blast shall be passed through a heated vessel or receptacle of any form or dimensions, such as a cast or malleable iron retort, kept to a dull red heat of some 1000° of temperature as the most desirable. It will readily be imagined that this apparatus, described in terms of so great generality, would assume various forms, according to the different views which the various practical men employed to construct the apparatus took of the most effective mode of heating the air. This is accordingly what occurred with the progress of time, and the increasing experience of those who used the apparatus; practical difficulties gradually diminished with the increased experience which was every day suggesting new and better expedients. It was also soon found that the advantage gained was increased in a rapid proportion with the degree of heat communicated to the air, so that the apparatus which gave at first some 300° of temperature to the air, and produced one measure of benefit, was soon superseded by a second form of apparatus giving 400°, and conferring still higher advantages; and this in its turn gave way to another and another, each giving a higher temperature to the air, and promising a higher degree of economy to the user. And thus at last a temperature between 600° and 700° was given to the air; a temperature higher than that of melting lead, which is indeed the criterion now generally applied to test the working heat of the blast.

Progress of improvement exhibited in the Butterly iron-works. We shall probably give our readers the clearest views of these general improvements, and of the progress which has generally taken place in carrying them into effect, by taking a single example. For this purpose we have selected the various modes of heating the air that have necessarily suggested themselves to, or been put in practice by the ingenious proprietors of the Butterly iron-works in Derbyshire, who were the first to introduce the hot-blast into that part of the country, and who have been among the most successful in carrying it into effect, and producing one of the most superior qualities of hot-blast iron.

Plate CCCCLXII. fig. 1, shows the construction of the

earliest and simplest plan by which the inventors of hot-blast first brought it into use. An iron vessel *hhh* was formed of malleable plates, rivetted together like a common steam-boiler, something near three feet in diameter, and eight or ten feet long, cylindrical, and fitted at the ends to two pipes *Bb*, communicating with the bellows, and *Ss* with the smelting furnace. Below this large pipe or tube a fire is placed, which is fed from the door *D*, and the whole is enclosed in an oven of brickwork *OOOO*, leaving a clear space all round the pipe *hhh*, so that the flame and hot air rising up and enveloping the receptacle, should keep it so hot as to communicate through the sides of the vessel a higher temperature to the air rushing through it, on its way from the bellows, *B*, towards the smelting furnace *S*. And in order to communicate this temperature more uniformly and completely to all the air passing through the vessel *hhh*, lunular partitions *ppp* proceeding alternately from opposite sides of the tube on its interior surface, cause the stream of air to impinge first on one side, and then on the other side of the heated iron pipe, as shown in the figure. By this apparatus a moderate current of air has been heated to three or four hundred degrees.

Fig. 2 shows the manner in which the method of heat-First ap- ing the air was employed at first in the Butterly iron-works. In the oven *OO* are placed the two cast-iron retorts *hh*, about thirty-two inches in diameter, and nine feet long, being of metal an inch and an eighth part in thickness. They are laid parallel to each other; one of them is at one end connected with the pipe *Bb* from the blowing apparatus, and this conducts the air from its other extremity through a curved junction pipe *JJ*, into the second receptacle *hh*; where, on its way becoming hot, it passes through the hot-air pipe *Ss*, from the heating furnace or oven, and is blown by the orifice *T* through the twyre *T* into the hearth of the smelting furnace at *F*. In this, as is usual, more than one blast, as at *T'*, was blown into the same smelting furnace. The fire *dd*, is placed at one corner of the oven on the bars *rr*, and is fed from the door *D*, and the smoke and flame rising up and surrounding *h'h'*, pass through a partition by the flue *f*, and fill the second compartment of the oven, clear spaces being left quite round the retorts on every side for the communication of the heat; only at the points *h* and *h*, they are supported by contact on the brick pillars *hh*. Finally, the products of combustion pass through a flue *f* into the short chimney *C*. In this way the cold air from the blast pipe *Bb* passing into the vessel *h'h'*, is partially heated, and is conducted into a second chamber, which, being placed immediately over the fire, is much more intensely hot, and from this second chamber at once discharged into the smelting furnace.

This apparatus was first tried in November 1830. The Its effects. air was only heated to 240°. Yet so admirable is the process, that it was attended with the following effect: With cold blast there were previously used at Butterly, 5½ tons coal (coked), to 1 ton of iron.

By the new apparatus there were required only 3 tons coal (raw), to 1 ton of iron.

So admirable an effect as this was not to be neglected on account of the practical difficulties attending it, which indeed only served as an inducement to further exertion; and in about a year after the following improved apparatus, with an increased number of tubular vessels, having increased dimensions of length, was successfully introduced.

Fig. 3. In the transverse section *h'h'h'*, are three pipes of cast-iron 1½ inch thick, being about 17 feet long, and about 22 inches in diameter. They are similarly denoted in the ground plan, and in the longitudinal section by the letters *h'h'h'*. The cold air pipe from the blowing apparatus *B*, enters the heating oven at *b* and traverses the pipe *h'h'* to the opposite end of the furnace: here a

Smelting
by hot-
blast.

bent pipe $h^1 h^2$ conveys the air into a second longitudinal pipe $h^2 h^2$, by which the stream of air returns back to the end of the oven at which it entered, and is conducted by a second bent pipe $h^2 h^3$ into the third tubular vessel $h^3 h^3$ in which it is for the last time exposed to the heated metal, and passes off from the heating oven into the smelting furnace, by the hot air pipe S, whence, as formerly, it is discharged through the twyre into the hearth of the furnace. The fuel is placed through the door D upon the fire of the oven on the bars r , and by means of a number of small pigeon holes ccc , ccc , ccc , is spread over the whole length of the pipes with some measure of uniformity, whereas, if allowed to act directly on the retorts, it would irregularly and less effectually heat their surface. The manner of protecting the retorts from the direct action of the fire, is well shown in the transverse section: a brick arch aaa is thrown over the fire, and the flame is only permitted to ascend through the aforesaid openings cc , cc . It will be noticed that the retorts are every where clear of the building and of each other, that they are wholly enclosed by the oven ooo ; and it will also be seen in the transverse section, and in the longitudinal section, that the products of combustion are carried off by a descending flue ff , regulated by a damper ee , into the short vertical chimney C. This damper is very useful in retarding the draught of air, so as to leave the products of combustion a longer time in contact with the heaters.

Its effects.

This apparatus is more effective and more durable than the last. It raised the heat of the air as high as 400° to 500° , being 200° higher than the former plan, as indeed we should expect from the greater number and length of the vessels, and the greater surface in contact with the air. The result, compared with the last, is as follows:

By the former plan with air at 240° ,

3 tons of coal were required

to melt 1 ton of iron.

By the improved plan, with air at 400° to 500° ,

$2\frac{1}{2}$ tons of coal were required

to melt 1 ton of iron.

The reader will not fail to be struck with the fact, that a much greater gain was obtained by the original ruder plan of using the air, when compared with the old system of hot-blast, than was afterwards got from the introduction of the improved apparatus over the former one. The higher temperature does not appear to have conferred an advantage at all proportionable to the increased temperature.

Third ap-
paratus.

Fig. 4 is a very superior and durable heating apparatus, which continues in efficient use to the present time. Its form is well adapted to prevent all the evils of expansion and contraction; and it is our opinion that by multiplying the vessels, a more effective apparatus might be made than any now in use. Its form is very ingenious, and its functions may be easily learned by studying the figure, in which the letters describe the same parts with those of the previous figures. B is the pipe coming from the blowing apparatus to the heating furnace $oooo$; S is the hot air pipe, proceeding from the heating oven to the smelting furnace; $h^1 h^1 h^1$ is a large retort into which the air is at first carried, and from the further end of which a malleable iron tube $i^1 i^1$, concentric with the retort, carries it back again to that end where it first entered, and through a bent pipe II conducts it along by a second interior tube $i^2 i^2$ to the further end of the second heater $h^2 h^2 h^2$, along the hot surface of which it returns in the manner shown by the arrows to the base of the second retort: now, this second retort communicates at the base with a third $h^3 h^3$, and after traversing its heated surface to the end, is brought back by a tube concentric with the axis to the base of the retort. This process might be continued with great advantage, and make one of the best series of heating vessels. The fire is covered by arches aaa , with small apertures ccc , as in the former case, to prevent the vessels from being injured by the local action of the intense fires.

This apparatus raised the temperature to between 500° and 600° , and produced a further saving in coals. By the former plan $2\frac{1}{2}$ tons of coal were required to smelt one ton of iron. By this improved apparatus, $2\frac{1}{2}$ tons of coal melted a ton of iron.

Figs. 5 and 6 are the general forms of apparatus now most extensively used. Fig. 5 is a form first given to the apparatus, we believe, by Mr. Dixon at Calder, and hence generally called the Calder pipes. Similar pipes were also early introduced at Gartsherrie, and at Wedensbury; and are very generally approved of from their extensive heating surface, although they are liable to the inconvenience of cracking, from unequal expansion. The form, as erected at Butterly, consists of two parallel horizontal pipes L L called technically "the lying pipes," one forming a communication immediately with the cold-blast pipe B, and the other with the hot-blast pipe S. Into sockets formed in the lying pipe, are inserted a series of smaller pipes springing up at right angles with the one lying pipe, and after forming an arch, returning down to the second lying pipe, being inserted in like manner into sockets in it. The air, therefore, on entering the first lying pipe, is forced through these transverse heating pipes, or "A pipes" as they are called from their figure, and thus exposed to the heat of a very extensive surface, is delivered into the hot-air pipe. Sometimes, as at Gartsherrie and many other works, there are several times as many pipes as in this example, and the air is made to cross and recross the fire several times.

The figures of the transverse pipes are as various as the taste of the parties who use them. Sometimes they rise up and form a large semicircular arch over the fire, which is placed in the centre; sometimes a double tier of such arches is employed. Sometimes they cross the fire in the form of a pointed arch variously acuminate. Then again by some, the pipes are carried up four, six, eight, or ten feet, like columns, united at the top by a semicircular arch.

The cross section of the heating pipe is as various as the form into which the pipe itself is made to bend. A circular pipe was used at first, then a flattened elliptical one for the purpose of exposing more surface in proportion to volume; next a pipe, flat at one part, and semicircular on the other, was introduced; next a pipe of a cardioid or heart-like section was employed. At Butterly Mr. Terrop used a circular pipe cast with a solid core, to keep the air near the hot surface, as shown in the figure; and finally, he employed the rectangular section as shown in our figure 6th. All of these appear to answer their purpose of heating the air sufficiently well, and all of them cause trouble and expense by cracking now and then.

The result of all these forms is to produce a hot-blast of more than 600° temperature, and at Butterly, figs. 5 and 6 yield as follows: $2\frac{1}{2}$ tons of coal melt one ton of iron. It is found, however, at Butterly, that pigs, for the forge, require about three cwt. less of coal than this average quantity, and that No. 1 iron requires about three cwt. more than this, as we should expect.

The Scotch use less coal than the Butterly Company, principally on this account, that the former use calcined ore, of which thirty-two cwt. with seven cwt. of lime, makes a ton of iron, while at Butterly, the quantity used for a ton of iron is $2\frac{3}{4}$ tons, with a ton of lime, being $3\frac{3}{4}$ tons of materials in one case, and less than two tons in the other.

The explanation of the principles from which hot-blast derives its efficacy as the means of producing elevated temperature, is very easy and plain to any one acquainted with the elementary principles of chemistry and mechanics. All that we think it necessary to add on this subject, we shall state in the words of Mr. Babbage and Dr. Ure.

"The increased effect," says Babbage, "produced by thus heating Mr. Babbage's air is by no means an obvious result; and an analysis of its action will lead to some curious views respecting the future application of machinery for blowing furnaces."

"Every cubic foot of atmospheric air, driven into a furnace, con-

Smelting
by hot-
blast.

Its effects.

Fourth and
fifth ap-
paratus.

Rationale
of the pro-
cess.

Smelting by hot-blast. consists of two gases;¹ about one-fifth being oxygen, and four-fifths azote. According to the present state of chemical knowledge, the oxygen alone is effective in producing heat; and the operation of blowing a furnace may be thus analyzed.

"1. The air is forced into the furnace in a condensed state, and, immediately expanding, abstracts heat from the surrounding bodies.

"2. Being itself of moderate temperature, it would, even without expansion, still require heat to raise it to the temperature of the hot substances to which it is to be applied.

"3. On coming into contact with the ignited substances in the furnace, the oxygen unites with them, parting at the same moment with a large portion of its latent heat, and forming compounds which have less specific heat than their separate constituents. Some of these pass up the chimney in a gaseous state, whilst others remain in the form of melted slags, floating on the surface of the iron, which is fused by the heat thus set at liberty.

"4. The effects of the azote are precisely similar to the first and second of those above described; it seems to form no combinations, and contributes nothing, in any stage, to augment the heat.

"The plan, therefore, of heating the air before driving it into the furnace, saves obviously the whole of that heat which the fuel must have supplied in raising it from the temperature of the external air up to that of 600° Fahrenheit; thus rendering the fire more intense, and the glassy slags more fusible, and perhaps also more effectually decomposing the iron ore. The same quantity of fuel, applied at once to the furnace, would only prolong the duration of its heat, not augment its intensity.

"The circumstance of so large a portion of the air² driven into furnaces being not merely useless, but acting really as a cooling, instead of a heating, cause, added to so great a waste of mechanical power in condensing it, amounting, in fact, to four-fifths of the whole, clearly shews the defects of the present method, and the want of some better mode of exciting combustion on a large scale."

The reader will find it interesting to compare this account with the following by Dr. Ure.

Dr. Ure's explanation.

"Wherever a forced stream of air is employed for combustion, the resulting temperature must evidently be impaired by the coldness of the air injected upon the fuel. The heat developed in combustion is distributed into three portions; one is communicated to the remaining fuel, another is communicated to the azote of the atmosphere, and to the volatile products of combustion, and a third to the iron and fluxes, or other surrounding matter to be afterwards dissipated by wider diffusion. This inevitable distribution takes place in such a way, that there is a nearly equal temperature over the whole extent of a fire-place, in which an equal degree of combustion exists.

"We thus perceive that if the air and the coal be very cold, the portions of heat absorbed by them might be very considerable, and sufficient to prevent the resulting temperature from rising to a proper pitch; but if they were very hot they would absorb less caloric, and would leave more to elevate the common temperature. Let us suppose two furnaces charged with burning fuel, into one of which cold air is blown, and into the other hot air, in the same quantity. In the same time, nearly equal quantities of fuel will be consumed with a nearly equal production of heat; but notwithstanding of this, there will not be the same degree of heat in the two furnaces, for the one which receives the hot air will be hotter by all the excess of heat in its air above that of the other, since the former air adds to the heat while the latter abstracts from it. Nor are we to imagine that by injecting a little more cold air into the one furnace, we can raise its temperature to that of the other. With more air indeed we should burn more coals in the same time, and we should produce a greater quantity of heat, but this heat being diffused proportionally among more considerable masses of matter, would not produce a greater temperature; we should have a larger space heated, but not a greater intensity of heat in the same space.

"Thus, according to the physical principles of the production and distribution of heat, fires fed with hot air should, with the same fuel, rise to a higher pitch of temperature than fires fed with common cold air. This consequence is independent of the masses, being as true for a small stove which burns only an ounce of charcoal in a minute, as for a furnace which burns a hundred weight; but the excess of temperature produced by hot air cannot be the same in small fires as in great; because the waste of heat is usually less the more fuel is burned.

"This principle may be rendered still more evident by a numeri-

cal illustration. Let us take, for example, a blast furnace, into which 600 cubic feet of air are blown per minute; suppose it to contain no ore but merely coal or coke, and that it has been burning long enough to have arrived at the equilibrium of temperature, and let us see what excess of temperature it would have if blown with air of 300° C. (572° F.) instead of being blown with air at 0° C.

"Six hundred cubic feet of air under the mean temperature and pressure, weigh a little more than 45 pounds avoirdupoise; they contain 10.4 pounds of oxygen, which would burn very nearly 4 pounds of carbon, and disengage 16,000 times as much heat as would raise by one degree cent. the temperature of two pounds of water. These 16,000 portions of heat, produced every minute, will replace 16,000 other portions of heat, dissipated by the sides of the furnace and employed in heating the gases, which escape from its mouth. This must take place in order to establish the assumed equilibrium of caloric.

"If the 45 pounds of air be heated beforehand up to 300° C., they will contain about the eighth part of the heat of the 16,000 disengaged by the combustion, and there will be therefore in the same space one-eighth of heat more, which will be ready to operate upon any bodies within its range, and to heat them one-eighth more. Thus the blast of 300° C. gives a temperature which is nine-eighths of the blast at zero C., or at even the ordinary atmospheric temperature; and as we may reckon at from 2200° to 2700° F. (from 1200° to 1500° C.) the temperature of blast furnaces worked in the common way, we perceive that the hot-air blast produces an increase of temperature equal to from 270° to 360° F.

"Now in order to appreciate the immense effects which this excess of temperature may produce in metallurgic operations, we must consider that often only a few degrees more temperature are required to modify the state of a fusible body, or to determine the play of affinities dormant at lower degrees of heat. Water is solid at 1° under 32° F.; it is liquid at 1° above. Every fusible body has a determinate melting point, a very few degrees above which it is quite fluid, though it may be pasty below it. The same observation applies to ordinary chemical affinities; charcoal, for example, which reduces the greater part of metallic oxides, begins to do so only at a determinate pitch of temperature, under which it is inoperative, but a few degrees above, it is in general lively and complete. It is unnecessary, in this article, to enter into any more details to show the influence of a few degrees of heat, more or less, in a furnace, upon chemical operations, or merely upon physical changes of state.

"These consequences might have been deduced long ago, and industry might thus have been enriched with a new application of science; but philosophers have been and still are too much estranged from the study of the useful arts, and content themselves too much with the minutiae of the laboratory or theoretic abstractions. Within the space of seven years, the use of the hot-blast has been so much extended in Great Britain, as to have enabled many proprietors of iron-works to add 50 per cent. to their weekly production of metal, to diminish the weekly expenses of smelting by 50 per cent., and, in many cases, to produce a better sort of cast-iron from indifferent materials."

The following table is from a report of M. Dufresnoy, made to the director-general of mines in France in 1834.

Cost of iron by hot-blast.

Cost price of a ton of pig-iron at the Clyde Iron-Works.

Materials used.	In 1829, with cold air.			In 1833, with hot air.		
	ton. cwt.	L. s. d.		ton. cwt.	L. s. d.	
Coal for fusion, at 5s. per ton,.....	6 13	1 13 3		2 0	0 10 0	
— for blowing machine, at 1s. 8d. per ton,.....	2 0	0 3 6		0 11	0 0 11	
— for the heating apparatus,.....	...	...		0 8	0 0 8	
Calcined ore, at 12s. per ton, ³	1 15	1 1 0		1 18	1 2 9	
Limestone, at 7s.....	10	0 3 6		...	0 3 6	
Labour, at 10s.....	...	0 10 0		...	0 10 0	
General charges, interests of capital, 6s.	...	0 6 0		...	0 6 0	
Total.....	L.3 17 3			L.2 13 10		

¹ The accurate proportions are, by measure, oxygen 21, azote 79.

² A similar reasoning may be applied to lamps. An argand burner, whether used for consuming oil or gas, admits almost an unlimited quantity of air. It would deserve inquiry, whether a smaller quantity might not produce greater light; and, possibly, a different supply furnish more heat with the same expenditure of fuel.

³ This mineral is very rich: the average produce of the iron mines of the Glasgow coal basin is 44 per cent. after calcination; in this state it costs from 8s. 6d. to 9s. per ton. The cost of the mineral will, therefore, be very nearly as stated in the table.

Smelting
by hot-
blast.

Since that period the cost has been rendered much lower, and those who have made good arrangements for mineral property, can manufacture iron at a cost of little more than L.2 per. ton.

Chemical
constitution
of hot-blast
iron.

At the request of the British Association, Dr. Thomson of Glasgow examined the chemical constitution of hot-blast iron, and he gives the following as the result of his inquiry:

"(1.) The specific gravity of hot-blast iron is greater than that of cold-blast.

"The following are the specific gravities of eight specimens of cold blast iron:

1st. Muirkirk.....	6.410
2nd. Ditto.....	6.435
3rd. Ditto.....	6.493
4th. Ditto.....	6.579
5th. Ditto.....	6.775
6th. From pyrites.....	6.9444
7th. From Carron.....	6.9888
8th. Clyde Iron Works.....	7.0028

"The specific gravity of the Muirkirk iron is considerably less than of that smelted at Carron and the Clyde Iron-Works; the mean of the eight specimens is 6.7034.

"It has been hitherto supposed that the difference between cast-iron and malleable iron consists in the presence of carbon in the former, and its absence from the latter; in other words, that cast iron is a carburet of iron. But in all the specimens of cast iron which we analysed we constantly found several other ingredients besides iron and carbon. Manganese is pretty generally present in minute quantity, though in one specimen it amounted to no less a quantity than 7 per cent.; its average amount is 2 per cent. Silicon is never wanting, though its amount is exceedingly variable, the average quantity is about $1\frac{1}{2}$ per cent.; some specimens contained $3\frac{1}{2}$ per cent. of it, while others contain less than a half per cent. Aluminum is very rarely altogether absent, though its amount is more variable than that of silicon. Its average amount is 2 per cent.; sometimes it exceeds $4\frac{1}{2}$ per cent., and sometimes it is not quite $\frac{1}{1000}$ th part of the weight of the iron.

"Calcium and magnesium are sometimes present, but very rarely, and the quantity does not much exceed $\frac{1}{100}$ th per cent. In a specimen of cast iron which I got from Mr. Neilson, and which he had smelted from pyrites, there was a trace of copper, showing that the pyrites employed was not quite free from copper; and in a specimen from the Clyde Iron-Works there was a trace of sulphur. The following table exhibits the composition of six different specimens of cast iron, No. 1, analyzed in my laboratory, either by myself or by Mr. John Tennent.

	Muirkirk.	Muirkirk.	Muirkirk.	Pyrites.	Carron.	Clyde.	Mean.
Iron,.....	90.98	90.29	91.38	89.442	94.010	90.824	91.154
Copper,.....	...	...	...	0.288	...	...	...
Manganese,...	...	7.14	2.00	...	0.626	2.458	2.037
Sulphur,....	...	...	...	...	...	0.045	...
Carbon,.....	7.40	1.706	4.88	3.600	3.086	2.458	3.855
Silica,.....	0.46	0.830	1.10	3.220	1.006	0.450	1.177
Aluminum,...	0.48	0.016	...	3.776	1.032	4.602	1.651
Calcium,....	...	0.018	0.20	...	...	...	...
Magnesium,...	...	...	...	...	...	0.340	...

"The constant constituents of cold-blast cast-iron, No. 1, are iron, manganese, carbon, silicon, and aluminum. The occasional constituents are copper, sulphur, calcium, and magnesium. These occur so rarely, and in such minute quantity, that we may overlook them altogether.

"The constant constituents occur in the following mean atomic proportions:

22 atoms iron,.....	= 77.00
$\frac{1}{2}$ atom manganese,.....	= 1.75
4.36 atoms carbon,.....	= 3.27
1 atom silicon,.....	= 1.00
$1\frac{1}{2}$ aluminum,.....	= 1.40—84.42

"2. I examined only one specimen of cast-iron, No. 2. It was an old specimen, said to have come from Sweden, but I have no evidence of the correctness of this statement. Its specific gravity was 7.1633 higher than any specimens of cold-blast iron, No. 1. Its constituents were,

Iron,.....	93.594
Manganese,.....	0.708
Carbon,.....	3.080
Silicon,.....	1.262
Aluminum,.....	0.732
Sulphur,.....	0.038—99.414

"The presence of sulphur in this specimen leads to the suspicion that it is not a Swedish specimen; for as the Swedish ore is magnetic iron, and the fuel charcoal, the presence of sulphur in the iron is very unlikely.¹

"In this specimen, the atoms of iron and manganese are to those of carbon, silicon, and aluminum, in the proportion of $4\frac{1}{2}$ to one, instead of $3\frac{1}{2}$ to one, as in cast-iron No. 1.

"The atoms of carbon, silicon, and aluminum, approach the proportions of 7, 2, and 1, so that in cast-iron, No. 2, judging from one specimen, there is a greater proportion of carbon, compared with the silicon and aluminum, than in cast-iron, No. 1.

"Mr. Tennent analyzed a specimen of hot blast-iron, No. 2, from Gartsherry. Its specific gravity was 6.9156, and its constituents,

		Atoms.
Iron,.....	90.542	25.86
Manganese,.....	2.764	0.78
Carbon,.....	3.094	4.05
Silicon,.....	0.680	0.68
Aluminum,.....	2.894	2.31
Sulphur,.....	0.023	0.011
	99.997	

So that it resembles cast-iron, No. 1, in the proportion of its constituents. The carbon is almost the same as in cold-blast iron, No. 2, but the proportion of aluminum is four times as great, while the silicon is little more than half as much. The atomic ratios are, carbon, 4; silicon, 0.67; aluminum, 2.28.

"3. Five specimens of hot-blast cast iron, No. 1, were analyzed. Two of these were from Carron, and three from the Clyde Iron-Works, where the hot-blast originally began; and where, of course, it has been longest in use. The specific gravity of these specimens was found to be as follows:

1st. From Clyde Works.....	7.0028
2d. From Carron,.....	7.0721
3d. From Carron,.....	7.0721
4th. From Clyde Works,.....	7.1022

Mean,..... 7.0623

"It appears from this, that the hot-blast increases the specific gravity of cast-iron by about $\frac{1}{2}$ nd part. It approaches nearer the specific gravity of cast iron No. 2, smelted by cold air, than to that of No. 1.

"The following table exhibits the constituents of these four specimens.

	Clyde.	Carron.	Carron.	Clyde.	Clyde.
Iron,.....	97.096	95.422	96.09	94.966	94.345
Manganese,...	0.332	0.336	0.41	0.160	3.120
Carbon,.....	2.460	2.400	2.48	1.560	1.416
Silicon,.....	0.280	1.820	1.49	1.322	0.520
Aluminum,...	0.385	0.488	0.26	1.374	0.599
Magnesium,...	...	...	...	0.792	...
	100.55	100.466	100.73	100.174	100.

The mean of these analyses gives us,

		Atoms.
Iron,.....	95.584 or 27.31	6.5
Manganese,.....	0.871 or 0.249	
Carbon,.....	2.099 or 2.79	1.
Silicon,.....	1.086 or 1.086	
Aluminum,.....	0.422 or 0.337	

101.285

Or, in the proportion of $6\frac{1}{2}$ atoms of iron and manganese to 1 atom of carbon, silicon, and aluminum. In the cold-blast cast-iron we have,

	Iron.	Carbon. &c.
In No. 1,.....	$3\frac{1}{2}$ atoms	1 atom.
In No. 2,.....	$4\frac{1}{2}$	1 —
In hot-blast,.....	$6\frac{1}{2}$	1 —

"Thus it appears, that when iron is smelted by the hot-blast its specific gravity is increased, and it contains a greater proportion of iron, and a smaller proportion of carbon, silicon, and aluminum, than when smelted by the cold-blast.

¹ I have been told by Mr. Mushet that the Swedes add sulphur to their iron No. 2.

Smelting
by hot-
blast.

Smelting by hot-blast. At the request of the British Association, Mr. Eaton Hodgkinson examined the mechanical properties of hot and cold-blast iron. The following are his general results.

Carron Iron, No. 2.

Strength of hot-blast iron.

	Cold-Blast.	Hot-Blast.	Ratio representing Cold Blast by 1000.
Tensile strength in lbs. per square inch.....	16683 (2)	13505 (3)	1000 : 809
Compressive ditto in lbs. per inch from castings torn asunder....	106375 (3)	108540 (2)	1000 : 1020
Do. from prisms of various forms	100631 (4)	100738 (2)	1000 : 1001
Do. from cylinders	125403 (13)	121685 (13)	1000 : 970
Transverse strength from all the experiments	 (11)	 (13)	1000 : 991
Power to resist impact	 (9)	 (9)	1000 : 1005
Transverse strength of bars one inch square in lbs.....	476 (3)	463 (3)	1000 : 973
Ultimate deflection of do. in in.	1.313 (3)	1.337 (3)	1000 : 1018
Modulus of elasticity in lbs. per square inch.....	17270500 (2)	16085000 (2)	1000 : 931
Specific gravity.....	7066	7046	1000 : 997

Devon Iron, No. 3.

Tensile strength.....		21907 (1)	
Compressive ditto		145435 (4)	
Transverse ditto from the experiments generally	 (5)	 (5)	1000 : 1417
Power to resist impact	 (4)	 (4)	1000 : 2786
Transverse strength of bars one inch square	448 (2)	537 (2)	1000 : 1199
Ultimate deflection ditto.....	.79 (2)	1.09 (2)	1000 : 1380
Modulus of elasticity ditto.....	22907700 (2)	22473650 (2)	1000 : 981
Specific gravity.....	7295 (4)	7229 (2)	1000 : 991

Buffy Iron, No. 1.

Tensile strength.....	17466 (1)	13434 (1)	1000 : 769
Compressive ditto...	93366 (4)	86397 (4)	1000 : 925
Transverse ditto.....	 (5)	 (5)	1000 : 931
Power to resist impact	 (2)	 (2)	1000 : 963
Transverse strength of bars one inch square	463 (3)	436 (3)	1000 : 942
Ultimate deflection do.....	1.55 (3)	1.64 (3)	1000 : 1058
Modulus of elasticity ditto.....	15381200 (2)	13730500 (2)	1000 : 893
Specific gravity.....	7079	6998	1000 : 989

Coed-Talon Iron, No. 2.

Tensile strength.....	18855 (2)	16676 (2)	1000 : 884
Compressive ditto...	81770 (4)	82739 (4)	1000 : 1012
Specific gravity.....	6955 (4)	6968 (3)	1000 : 1002

Carron Iron, No. 3.

Smelting by hot-blast || Smith.

	Cold-Blast.	Hot-Blast.	Ratio representing Cold Blast by 1000.
Tensile strength.....	14200 (2)	17755 (2)	1000 : 1250
Compressive ditto...	115442 (4)	133440 (3)	1000 : 1156
Specific gravity.....	7135 (1)	7056 (1)	1000 : 989

"Of the three columns of numbers in the table above, the first is the strength or other quality in the cold-blast iron; the second is that in the hot-blast; and the third is the ratio of these quantities.

"The results in this table contain nearly the whole information relative to the question of hot and cold-blast-iron that the preceding research affords; and before adverting to them, it may be mentioned, that it is usual for the makers of cast-iron to divide it, when taken from the furnace, into three classes, called Nos. 1, 2, 3, differing from each other in the appearance and qualities of the material. No. 1 contains the softest and richest irons, those which have the largest crystals; No. 3, the hardest and densest irons, those with the least crystals; and No. 2, irons intermediate between the former two descriptions. Beginning with the No. 1 iron, of which we have a specimen from the Buffery Iron-Works, a few miles from Birmingham, we find the cold-blast iron somewhat surpassing the hot-blast in all the following particulars; direct tensile strength, compressive strength, transverse strength, power to resist impact, modulus of elasticity or stiffness, specific gravity; whilst the only numerical advantage possessed by the hot-blast iron is, that it bends a little more than the cold-blast before it breaks.

"In the irons of the quality No. 2, the case seems in some degree different; in these the advantages of the rival kinds seem to be more nearly balanced. They are still, however, rather in favour of the cold blast.

"Referring to the No. 2 iron, from the Carron Works in Scotland, we find the tensile, compressive, and transverse strengths, together with the modulus of elasticity and specific gravity, all higher in the cold-blast iron than the hot-blast, whilst the ultimate deflection and power of sustaining impact are greater in the hot-blast. The cold-blast iron is the better, but the difference is very small.

"In the iron No. 2, from the Coed-Talon Works in North Wales, the tensile strength is greater in the cold-blast than in the hot; but the resistance to compression is higher in the latter than the former, and that is the case with the specific gravity.

"So far as my experiments have proceeded, the irons of No. 1 have been deteriorated by the hot-blast; those of No. 2 appear also to have been slightly injured by it; while the irons of No. 3 seem to have benefited by its mollifying powers. The Carron iron No. 3, hot-blast, resists both tension and compression with considerably more energy than that made with the cold-blast; and the No. 3 hot-blast iron from the Devon Works, in Scotland, is one of the strongest cast-irons I have seen, whilst that made with the cold-blast is comparatively weak, though its specific gravity is very high, and higher than in the hot. The extreme hardness of the cold-blast Devon iron above prevented many experiments that would otherwise have been made upon it, no tools being hard enough to form the specimens. The difference of strength in the Devon irons is peculiarly striking.

"From the evidence here brought forward, it is rendered exceedingly probable that the introduction of a heated blast into the manufacture of cast-iron has injured the softer irons, whilst it has frequently mollified and improved those of a harder nature; and considering the small deterioration that the irons of the quality No. 2 have sustained, and the apparent benefit to those of No. 3, together with the great saving effected by the heated blast, there seems good reason for the process becoming as general as it has done." (C. A.)

SMITH, SIR THOMAS, was born at Walden in Essex, in the year 1512. At fourteen he was sent to Queen's College, Cambridge, where he distinguished himself so much, that he was made Henry the Eighth's scholar, together with John Cheke. He was chosen a fellow of his college in 1531, and appointed two years afterwards to read the public Greek lecture. The common mode of reading Greek at that time was very faulty, the same sound being given to the letters and diphthongs, *i, η, v, ei, oi, vi*. Smith and Cheke had been for some time sensible that this pronunciation was wrong; and after a good deal of consultation and research, they agreed to introduce that mode of reading which prevails at present. Smith was lecturing on Aristotle *De*

Smith. *Republica*, in Greek. At first he dropped a word or two at intervals in the new pronunciation, and sometimes he would stop as if he had committed a mistake, and correct himself. No notice was taken of this for two or three days; but as he repeated it more frequently, his audience began to wonder at the unusual sounds, and at last some of his friends mentioned to him what they had remarked. He owned that something was in agitation, but that it was not yet sufficiently digested to be made public. They entreated him earnestly to discover his project. He did so, and in a short time great numbers resorted to him for information. The new pronunciation was adopted with enthusiasm, and soon became universal at Cambridge. It was afterwards opposed by Bishop Gardiner the chancellor; but its superiority to the old mode was so visible, that in a few years it spread over all England.

In 1539 he travelled into foreign countries, and studied for some time in the universities of France and Italy. At Padua he took the degree of LL.D. On his return, he was admitted *ad eundem* at Cambridge, and was appointed regius professor of the civil law. He was useful in promoting the reformation of religion as well as of learning. Having gone into the family of the duke of Somerset the protector, during the minority of Edward the Sixth, he was employed by that nobleman in public affairs; and in 1548 he was made secretary of state, and received the honour of knighthood. While Somerset continued in office, he was sent as ambassador, first to Brussels, and afterwards to France. Upon the accession of Mary, he lost all his places, but was fortunate enough to preserve the friendship of Gardiner and Bonner. He was exempted from persecution, and was allowed, probably by their influence, a pension of L.100. During Elizabeth's reign he was employed in public affairs, and was thrice sent to France in the capacity of an ambassador. He died in the year 1577.

Sir Thomas Smith was a man of excellent talents, united with solid and variegated learning. He obtained a respectable place among the scholars of the age, by the publication of his epistle to the bishop of Winchester, "*De recta et emendata Linguae Graecae Pronuntiatione.*" Lutetiae, 1568, 4to. The same volume includes his dialogue, "*De recta et emendata Linguae Anglicanae Scriptione.*" But the work by which he is best known in modern times, is entitled "*De Republica Anglorum: the Maner of Gouvernement or Policie of the Realme of England.*" Lond. 1583, 4to. Of this treatise, which was translated into Latin, there are many editions.

SMITH, EDMUND, an English poet, the only son of Mr. Neale, an eminent merchant, by a daughter of Baron Lechmere, was born in 1668. By his father's death, he was left young to the care of Mr. Smith, who had married his father's sister, and who treated him with so much tenderness, that at the death of his generous guardian, he assumed his name. His writings are not many, and these are scattered in miscellanies and collections. His celebrated tragedy of *Phædra* and *Hippolytus* was acted in 1707; and being introduced at a time when the Italian opera so much engrossed the attention of the polite world, gave Mr. Addison, who wrote the prologue, an opportunity to rally the vitiated taste of the public. Notwithstanding the esteem in which it has always been held, it is perhaps rather to be considered as a fine poem than as a good play. This tragedy, with a poem to the memory of Mr. John Philips, three or four odes, with a Latin oration spoken at Oxford, *In laudem Thomæ Bodleii*, were published as his works by his friend Mr. Oldisworth. Mr. Smith died in 1710.

SMITH, ADAM, was born at Kirkcaldy, on the 5th of June 1723. His father, who held the situation of comptroller of customs in that town, died a few months before his birth; so that the charge of his early education devolved wholly on his mother, the daughter of Mr. Douglas of Strathenry, in the county of

Fife. His constitution during infancy is said to have been extremely infirm and delicate, and required all the anxious attention of his mother, who treated him with the greatest indulgence. This did not, however, produce any unfavourable effect on his temper or dispositions; and he repaid the fond solicitude of his parent by every attention that filial gratitude and affection could dictate, during the long period of sixty years. When only three years of age, he was stolen from Strathenry, to which place he had been carried by his mother, by a party of gipsys. Fortunately, however, for the best interests of mankind, he was speedily recovered by the exertions of his uncle.

He received the first rudiments of his education in the grammar school of Kirkcaldy. The weakness of his constitution prevented him from indulging in the amusements common to boys of his age. But Mr. Stewart states, that he was even then distinguished by his passion for books, and by the extraordinary powers of his memory; that he was much beloved by his school-fellows, many of whom subsequently attained to great eminence, for his friendly and generous disposition; and that even then he was remarkable for those habits which remained with him through life, of speaking to himself when alone, and of mental absence in company. He continued at Kirkcaldy until 1737, when he was sent to the University of Glasgow, where he remained for three years. He then entered Balliol College, Oxford, as an exhibitor on Snell's foundation; and he continued for seven years to prosecute his studies at that celebrated seminary.

Mr. Stewart mentions, on the authority of Dr. MacLaine of the Hague, that mathematics and natural philosophy formed young Smith's favourite pursuits while at Glasgow. But subsequently to his removal to Oxford he seems to have entirely abandoned them, and to have principally devoted the time not consumed in the routine duty of the University to the study of polite literature, and of those moral and political sciences of which he was destined afterwards to become so great a master. Smith does not seem to have felt any very peculiar respect for his English *alma mater*. The severe remarks in the *Wealth of Nations* on the system of education followed in Oxford and Cambridge, had evidently been suggested by his own observation.

While he resided at Oxford, something had occurred to excite the suspicions of his superiors with respect to the nature of his private pursuits; and the heads of his college, having entered his apartment without his being aware, unfortunately found him engaged reading Hume's *Treatise of Human Nature*. The objectionable work was, of course, seized; the young philosopher being at the same time severely reprimanded.

Subsequently to his return from Oxford in 1747, he continued to reside for nearly two years at Kirkcaldy with his mother. He had been sent to Oxford that he might be qualified for entering the church of England. The ecclesiastical profession was not, however, agreeable to his taste; and in opposition to the advice of his friends, he returned to Scotland, resolved to devote himself exclusively to literary pursuits. In the latter part of the year 1748, he fixed his residence in Edinburgh, where, in consequence of the encouragement and persuasion of Lord Kames, and some of his other friends, he was prevailed upon to deliver, during that and the two following years, a course of lectures on rhetoric and polite literature. The lectures were attended by a respectable auditory, composed chiefly of students of law and theology; and he had the honour to reckon among his pupils Mr. Wedderburne, afterwards Lord Loughborough, Mr. William Johnstone, afterwards Sir William Pulteney, and Dr. Blair; with all of whom he subsequently continued on the most intimate terms. It was also at this period that he laid the foundation of that friendship with David Hume, which

Smith.

Smith. lasted, without the slightest interruption, till the death of the latter.

No part of these lectures was ever published; but it would appear from the statement of Dr. Blair, who commenced his course of Lectures on rhetoric in 1758, ten years after Dr. Smith's first course, that they had been reduced into a systematic form. In a note to his eighteenth lecture, Dr. Blair mentions that he had borrowed several of the ideas respecting the general characters of style, particularly the plain and simple, and the characters of those English authors who are classed under them, from a manuscript treatise of Dr. Smith on Rhetoric, of which the author had shewn him a part.

In consequence of his increasing celebrity, Dr. Smith was elected, in 1751, professor of logic in the University of Glasgow; and the year following he was elevated to the chair of moral philosophy in the same University, vacant by the death of Mr. Craigie, the immediate successor of the celebrated Dr. Hutcheson, under whom Dr. Smith had formerly studied. He continued to hold this situation for thirteen years; and, as the studies and inquiries in which his academical duties daily engaged him, were the most agreeable to his taste, it is not surprising that he should have considered the period of his residence at Glasgow as the happiest portion of his life. At the same time, it seems reasonable to conclude that his professional pursuits must have had a great effect in maturing his speculations in morals and politics, and, consequently, in determining him to undertake those great works which have immortalized his name, and largely benefited the whole human race.

Mr. Millar, the distinguished author of the *Historical View of the English Government*, and professor of law in the University of Glasgow, had the advantage of hearing Dr. Smith's course of lectures on moral philosophy; of which he has given the following account: "There was no situation in which the abilities of Dr. Smith appeared to greater advantage than as a professor. In delivering his lectures, he trusted almost entirely to extemporary elocution. His manner, though not graceful, was plain and unaffected; and, as he seemed to be always interested in the subject, he never failed to interest his hearers. Each discourse consisted commonly of several distinct propositions, which he successively endeavoured to prove and illustrate. These propositions, when announced in general terms, had, from their extent, not unfrequently something of the air of a paradox. In his attempts to explain them, he often appeared, at first, not to be always interested in the subject, and spoke with some hesitation. As he advanced, however, the matter seemed to crowd upon him, his manner became warm and animated, and his expression easy and fluent. In points susceptible of controversy, you could easily discern, that he secretly conceived an opposition to his opinions, and that he was led upon this account to support them with greater energy and vehemence. By the fulness and variety of his illustrations, the subject gradually swelled in his hands, and acquired a dimension which, without a tedious repetition of the same views, was calculated to seize the attention of his audience, and to afford them pleasure, as well as instruction, in following the same object through all the diversity of shades and aspects in which it was presented, and afterwards in tracing it backwards to that original proposition or general truth from which this beautiful train of speculation had proceeded.

"His reputation as a professor was accordingly raised very high, and a multitude of students from a great distance resorted to the University, merely upon his account. Those branches of science which he taught became fashionable at this place, and his opinions were the chief topic of discus-

sion in clubs and literary societies. Even the small peculiarities in his pronunciation or manner of speaking became frequently the objects of imitation."

It is understood that Dr. Smith made his debüt as an author by contributing, anonymously, two articles to a publication entitled the *Edinburgh Review*, commenced in 1755, of which only two numbers were published. The first of these articles is a review of Dr. Johnson's Dictionary, and displays considerable acuteness; the second is in the form of a letter to the editor, and contains some general observations on the literature of the different European countries. It is chiefly remarkable as evincing the attention paid by the author to continental literature, at a period when it was comparatively neglected in this country.

In 1759 Smith published his *Theory of Moral Sentiments*. He had been engaged for a very considerable period in the composition of this work, which is throughout elaborated with the greatest care. The fundamental principle maintained by the author is, that *sympathy* forms the real foundation of morals; that we do not immediately approve or disapprove of any given action, when we have become acquainted with the intention of the agent and the consequences of what he has done, but that we previously enter, by means of that sympathetic affection which is natural to us, into the feelings of the agent and those to whom the action relates; that, having considered all the motives, and passions by which the agent was actuated, we pronounce, with respect to the *propriety* or *impropriety* of the action, according as we sympathize or not with him; while we pronounce, with respect to the *merit* or *demerit* of the action, according as we sympathize with the gratitude or resentment of those who were its objects; and that we necessarily judge of our own conduct by comparing it with such maxims and rules as we have deduced from observations previously made on the conduct of others.

Several, and, as it is now generally admitted, some unanswerable, objections have been urged against this most ingenious theory. But, whatever difference of opinion may exist with respect to the truth of the principle it involves, the *Theory of Moral Sentiments* has been universally allowed to abound in the most admirable disquisitions, in a faithful and skilful delineation of character, and in the soundest and most elevated maxims for the practical regulation of human life. The style various, but always eloquent, is worthy of the subject; and while it serves, by the beauty and richness of its colouring, to relieve the dryness of some of the more abstract discussions, it gives additional force to the powerful recommendations of generous, upright, and disinterested conduct to be found in every part of the work.

Dr. Brown, who has criticised this theory with his usual acuteness, and has shewn that though sympathy may diffuse moral sentiments, it can never originate them, bears, notwithstanding, the strongest testimony to the transcendent merits of Dr. Smith's work. "The *Theory of Moral Sentiments*," he observes, "is, without all question, one of the most interesting works, perhaps I should have said the most interesting work, in moral science. It is valuable, however, as I before remarked, not for the leading doctrine, of which we have seen the fallacy, but for the minor theories which are adduced in illustration of it; for the refined analysis which it exhibits in many of its details; and for an eloquence which, adapting itself to all the temporary varieties of its subject, familiar, with a sort of majestic grace, and simple even in its magnificence, can play amid the little decencies and proprieties of common life, or rise to all the dignity of that sublime and celestial virtue, which it seems to bring from heaven indeed, but to bring down gently and humbly, to the bosom of man."¹

¹ Brown's Lectures, vol. iv. p. 132. edit. 1824.

Smith.

Having published the substance of so important a part of his lectures, Smith was enabled to make considerable retrenchments from the ethical parts of his course, and to give a proportionally greater extension to the disquisitions on Jurisprudence and Political Economy. He had long been in the habit of embodying in his lectures the results of his studies and investigations with respect to both these departments of political science, and particularly the latter; and it appears from a statement which he drew up in 1755, in order to vindicate his claims to certain political and literary opinions, that he had been in the habit of teaching, from the time he obtained a chair in the University of Glasgow, and even when at Edinburgh, the same enlarged and liberal doctrines with respect to the freedom of industry, and the impolicy and injurious influence of artificial restraints and regulations, which he afterwards so fully established in the *Wealth of Nations*. His residence in a large commercial city, like Glasgow, gave him considerable advantage in the prosecution of his favourite studies, by affording means of easily obtaining that correct practical information, on many points, which cannot be learned from books, and by enabling him to compare his theoretical doctrines with the experimental conclusions of his mercantile friends. Notwithstanding the disinclination so common among men of business, to listen to speculative opinions, and the opposition of his leading principles to the old maxims of trade, he was able, before he quitted his situation in the University, to rank some very eminent merchants among his proselytes.

The publication of the *Theory of Moral Sentiments* brought a great accession of reputation to the author; and placed him, in the estimation of all who were qualified to form an opinion on such a subject, in the first rank of moralists, and of able and eloquent writers. In 1762 the Senate of the University of Glasgow unanimously conferred on him the degree of Doctor of Laws; in testimony, as it is expressed in the minutes of the meeting, of their respect for his universally acknowledged talents, and of the advantage that had resulted to the University from the ability with which he had for many years expounded the principles of jurisprudence. But the most important effect of his increasing celebrity, in so far at least as respected himself, was his receiving in 1763 an invitation from Mr. Charles Townsend, who had married the Duchess of Buccleugh, to attend her Grace's son, the young Duke, on his travels; and the advantageous terms that were offered, combined with the strong desire which he entertained of visiting the Continent, induced him to accept the offer, and to resign his chair at Glasgow. "With the connexion which he was led to form in consequence of this change in his situation," says Mr. Stewart, "he had reason to be satisfied in an uncommon degree, and he always spoke of it with pleasure and gratitude. To the public it was not, perhaps, a change equally fortunate; as it interrupted that studious leisure for which nature seems to have destined him, and in which alone he could have hoped to accomplish those literary projects which had flattered the ambition of his youthful genius."

Dr. Smith set out for France in company with his noble pupil in March 1764. They remained only a very few days at Paris on their first visit to that capital, but proceeded to Toulouse, where they resided for about eighteen months. The society of Toulouse, a considerable city, and at that time the seat of a parliament, must have been a good deal supe-

rior to that of most country towns; and Dr. Smith would, no doubt, avail himself of it, and of the leisure he then enjoyed, to perfect and extend his knowledge of the literature, internal policy, and state of France. He has told us that he was not disposed to place much confidence in the facts and reasonings of political arithmeticians; and it is evident, from his rarely stating facts on the authority of others, and from the references he occasionally makes to circumstances connected with Toulouse, Geneva, and other places which he visited, that he was chiefly indebted to his own observation and inquiries for the accurate and extensive information he is universally acknowledged to have possessed with respect to the institutions, habits, and condition of the French people.

After leaving Toulouse, Dr. Smith and his pupil proceeded to Geneva, where they resided two months. They returned to Paris at Christmas, 1765, and remained in that city for nearly twelve months. During the whole of this period, Dr. Smith lived on the most friendly footing with the best society in Paris. Turgot, afterwards comptroller general of Finance, D'Alembert, Helvetius, Marmontel, the Abbé Morellet,¹ the Duc de la Rochefoucault, and Madame Riccoboni, were of the number of his acquaintances; and some of them he continued ever after to reckon among his friends. He was also on familiar terms with M. Quesnay, founder of the sect of the Economists; and there is every reason to think that he derived considerable advantage from his intercourse with that able and excellent person, than whom none was better qualified to strike out original and ingenious views. So sensible, indeed, was Dr. Smith of his great and various merits as a man and a philosopher, that he intended, had he not been prevented by Quesnay's death, to have left a lasting testimony of the estimation in which he held him, by dedicating to him the *Wealth of Nations*.

In October 1766, the Duke of Buccleugh and Dr. Smith returned to London. The latter soon after removed to his old residence at Kirkcaldy; where he continued to reside, with very little interruption, for about ten years, habitually occupied in study, and in the elaboration of his great work. The *Inquiry into the Nature and Causes of the Wealth of Nations* appeared in 1776; an æra that will be for ever memorable in the history of political philosophy. Of this invaluable work, it is sufficient to observe, that, notwithstanding the defects that have been discovered in some of its principles, and the objections that have been made, and, perhaps, with justice, to its arrangement, it will ever remain one of the noblest monuments of profound sagacity, great and varied learning, sound judgment, and persevering research, directed to the best, because the most useful, purposes. There can be no question with respect to the claim of Dr. Smith to be considered as the real founder of the modern system of Political Economy. Though he has not left a perfect work, he has left one which contains a greater number of useful truths than have ever been given to the world by any other individual; and he has pointed out and smoothed the route, by following which subsequent philosophers have been able to perfect much that he left incomplete, to rectify the mistakes into which he fell, and to make many new and important discoveries. Whether indeed we refer to the soundness of its leading doctrines, the liberality and universal applicability of its practical conclusions, or the powerful and beneficial influence which it has had on the progress of economical science, and on the policy and conduct of nations, the *Wealth of Nations* must be placed in

Smith.

¹ The paragraph which follows is extracted from the Mémoires of the Abbé Morellet published in 1821. "J'avais connu Smith dans un voyage qu'il avait fait en France, vers 1762; il parlait fort mal notre langue; mais sa *Théorie des Sentimens Moraux*, publiée en 1759, m'avait donné une grande idée de sa sagacité et de sa profondeur. Et véritablement je le regarde encore aujourd'hui comme une des hommes qui a fait les observations et les analyses les plus complètes dans toutes les questions qu'il a traitées. M. Turgot, qui animait ainsi que moi la métaphysique, estimait beaucoup son talent. Nous le vîmes plusieurs fois; il fut présenté chez Helvétius: nous parlâmes théorie commerciale, banque, crédit public, et de plusieurs points du grand ouvrage qu'il méditait. Il me fit présent d'un fort joli portefeuille anglais de poche, qui était à son usage, et dont je me suis servi vingt ans." Tom. i. p. 237.

Smith. the foremost rank of those works that have helped to liberalize, enlighten, and enrich mankind.

Dr. Smith survived the publication of the *Wealth of Nations* fifteen years. He had the satisfaction to see it translated into all the languages of Europe; to hear his opinions quoted in the House of Commons; to be consulted by the minister; and to observe that the principles which he had expounded were beginning to produce a material change in the public opinion, and in the councils of this and other countries; and he must have enjoyed the full conviction that the progress of events would ensure their ultimate triumph, by showing that they were productive of signal advantage, not only to the general mass of mankind, but to the inhabitants of every country which should have good sense enough to adopt them.

Mr. Hume died very soon after the publication of the *Wealth of Nations*. Dr. Smith, with whom he had long lived on the most intimate terms, was most assiduous in his attentions to his illustrious friend during his illness; and he gave a brief account of the circumstances connected with his death, together with a sketch of his character, in a letter addressed to Mr. Strahan of London, which was soon after published as a supplement to Mr. Hume's autobiography. The unqualified eulogium pronounced in this letter on Mr. Hume's character excited the indignation of those who took offence at his religious opinions. Dr. Horne, bishop of Norwich, in an anonymous letter, attacked Dr. Smith on this ground; and very naturally ascribed to him the same sceptical opinions that had been entertained by his deceased friend. But he took no notice of this attack; and wisely declined entering upon a controversy that could have led to no useful result.

Dr. Smith resided principally in London during the two years immediately subsequent to the publication of the *Wealth of Nations*; caressed by the most distinguished persons in the metropolis, who were justly proud of his acquaintance, and who, though they could not always subscribe to the justice of his remarks, were equally delighted with the goodness of his heart, the simplicity of his manners, the vigour of his understanding, and the variety of his attainments. In 1788 he was appointed, through the unsolicited application of his old pupil and friend, the Duke of Buccleugh, a commissioner of customs for Scotland. In consequence of this appointment he removed to Edinburgh, where he continued afterwards to reside, possessed of an income more than equal to his wants, and in the enjoyment of the society of his earliest and most esteemed friends. His mother, then in extreme old age, and his cousin, Miss Douglas, accompanied him to Edinburgh, the latter superintending the domestic arrangements and economy of his family. But though his appointment to the customs reflects high credit on the nobleman by whose intervention it was procured, it may be doubted whether it was worthy of the country or of Dr. Smith. The philosopher who had produced a work in which the true sources of national wealth and prosperity were, for the first time, fully explored and laid open, deserved a different and a higher reward.

In 1787 Dr. Smith was elected Lord Rector of the University of Glasgow; on which occasion he addressed a letter to that learned body, which strikingly evinces the high sense he felt of this honour, and his affectionate regard for those from which it emanated. "No preferment," says he, "could have given me so much real satisfaction. No man can owe greater obligations to a society than I do to the University of Glasgow. They educated me; they sent me to Oxford. Soon after my return to Scotland, they elected

me one of their own members; and afterwards preferred me to another office, to which the abilities and virtues of the never to be forgotten Dr. Hutcheson had given a superior degree of illustration. The period of thirteen years, which I spent as a member of that society, I remember as by far the most useful, and therefore as by far the happiest and most honourable, period of my life; and now, after three and twenty years' absence, to be remembered in so very agreeable a manner by my old friends and protectors, gives me a heartfelt joy which I cannot easily express to you."

His constitution, which had at no time been robust, began early to give way; and his decline was accelerated by the grief and vexation he felt on account of the death of his mother, to whom he had been most tenderly attached, in 1784, and of Miss Douglas, in 1788. He survived the latter only about two years, having died in July 1790. His last illness, which was occasioned by a chronic obstruction of the bowels, was both tedious and painful: but he bore it with the greatest fortitude and resignation: his cheerfulness never forsook him; and he had all the consolation that could be derived from the affectionate sympathy and attention of his friends.

His conduct in private life did not belie the generous principles inculcated in his works. He was in the habit of allotting a considerable part of his income to offices of secret charity. Mr. Stewart mentions that he had been made acquainted with some very affecting instances of his beneficence. "They were all," he observes, "on a scale much beyond what might have been expected from his fortune; and were accompanied with circumstances equally honourable to the delicacy of his feelings and the liberality of his heart."

Dr. Smith collected an exceedingly valuable and well-selected, though not a very extensive, library. He was very particular, not only with respect to the books themselves, but also with respect to the condition of the copies admitted into his collection. "The first time," says Mr. Smellie, "I happened to be in his library, observing me looking at the books with some degree of curiosity and perhaps surprise, for most of the volumes were elegantly and some of them superbly bound, 'You must have remarked,' said he, 'that *I am a beau in nothing but my books.*'"¹ His library is still in the possession of Lord Reston's widow.

Notwithstanding the apparent flow and artlessness of his style, and his great experience in composition, Dr. Smith stated, not long before his death, that he continued to compose as slowly, and with as great difficulty, as at first. He did not write with his own hand, but generally walked up and down his apartment, dictating to an amanuensis.²

Dr. Smith had been long resolved that none of his manuscripts, except those which he himself judged fit for publication, should ever see the light; and a few days before his death he carried this resolution into effect, by having all his papers committed to the flames, with the exception of the fragments of some essays, intended to illustrate the principles that lead and direct philosophical inquiries, which he left to the discretion of his friends to publish or not as they thought proper. The contents of the manuscripts that were destroyed are not exactly known; but they certainly contained the course of lectures on rhetoric delivered at Edinburgh in 1748, and the lectures on jurisprudence and natural religion, which formed a most important part of the course of moral philosophy delivered at Glasgow. The loss of the latter must ever be a subject of deep regret. We are ignorant of the motives which induced Dr. Smith to destroy them; but Mr. Stewart supposes that it was not

¹ Smellie's *Lives*, p. 296.

² Mr. Stewart states that all Hume's works were written with his own hand; and that the last volumes of his history were printed from the original copy, with only a few marginal corrections.

Smith. so much on account of any apprehended injury to his literary reputation from the publication of such unfinished works, as from an anxiety lest the progress of truth should be retarded by the statement of doctrines of which the principles were not fully developed.

The following observations on the private character and habits of Dr. Smith proceed from the pen of Mr. Stewart, who knew him well, and who was the last survivor of that galaxy of illustrious men who shed, during the last century, so imperishable a glory over the literature of Scotland. "The more delicate and characteristical features of his mind," Mr. Stewart observes, "it is perhaps impossible to trace. That there were many peculiarities, both in his manners and in his intellectual habits, was manifest to the most superficial observer; but although, to those who knew him, these peculiarities detracted nothing from the respect which his abilities commanded; and although, to his intimate friends, they added an inexpressible charm to his conversation, while they displayed, in the most interesting light, the artless simplicity of his heart; yet it would require a very skilful pencil to present them to the public eye. He was certainly not fitted for the general commerce of the world, or for the business of active life. The comprehensive speculations with which he had been occupied from his youth, and the variety of materials which his own invention continually supplied to his thoughts, rendered him habitually inattentive to familiar objects, and to common occurrences; and he frequently exhibited instances of absence, which had scarcely been surpassed by the fancy of La Bruyere. Even in company he was apt to be engrossed with his studies; and appeared at times, by the motion of his lips, as well as by his looks and gestures, to be in the fervour of composition. I have often, however, been struck, at the distance of years, with his accurate memory of the most trifling particulars; and am inclined to believe, from this and some other circumstances, that he possessed a power, not perhaps uncommon among absent men, of recollecting, in consequence of subsequent efforts of reflection, many occurrences which, at the time when they happened, did not seem to have sensibly attracted his notice.

"To the defect now mentioned, it was probably owing, in part, that he did not fall in easily with the common dialogue of conversation, and that he was somewhat apt to convey his own ideas in the form of a lecture. When he did so, however, it never proceeded from a wish to engross the discourse, or to gratify his vanity. His own inclination disposed him so strongly to enjoy in silence the gaiety of those around him, that his friends were often led to concert little schemes, in order to engage him in the discussions most likely to interest him. Nor do I think I shall be accused of going too far when I say, that he was scarcely ever known to start a new topic himself, or to appear unprepared upon those topics that were introduced by others. Indeed, his conversation was never more amusing than when he gave a loose to his genius upon the very few branches of knowledge of which he only possessed the outlines.

"The opinions he formed of men, upon a slight acquaintance, were frequently erroneous; but the tendency of his nature inclined him much more to blind partiality than to ill-founded prejudice. The enlarged views of human affairs, on which his mind habitually dwelt, left him neither time nor inclination to study, in detail, the uninteresting peculiarities of ordinary characters; and accordingly, though intimately acquainted with the capacities of the intellect, and the workings of the heart, and accustomed, in his theories, to mark, with the most delicate hand, the nicest shades, both of genius and of the passions; yet, in judging of individuals, it sometimes happened that his estimates were, in a surprising degree, wide of the truth.

"In his external form and appearance there was nothing uncommon. When perfectly at ease, and when warmed

Smith. with conversation, his gestures were animated, and not ungraceful; and, in the society of those he loved, his features were often brightened with a smile of inexpressible benignity. In the company of strangers, his tendency to absence, and perhaps still more his consciousness of this tendency, rendered his manner somewhat embarrassed;—an effect which was probably not a little heightened by those speculative ideas of propriety, which his recluse habits tended at once to perfect in his conception, and to diminish his power of realizing."

The following is a list of the published works of Dr. Smith.

1. Two articles in the *Edinburgh Review* for 1755, being, (1) a Review of Johnson's *English Dictionary*, and (2) *A Letter to the Editors*.

2. *The Theory of Moral Sentiments*. The first edition of this work was published in 8vo, early in 1759. The sixth edition was published a short time before the author's death. It contains several additions, most of which were executed during his last illness.

3. *Considerations concerning the first Formation of Languages, and the different Genius of Original and Compounded Languages*. This essay was originally subjoined to the first edition of the *Moral Sentiments*. It is an ingenious and pretty successful attempt to explain the formation and progress of language, by means of that species of investigation to which Dugald Stewart has given the appropriate name of *Theoretical or Conjectural History*; and which consists in endeavouring to trace the progress and vicissitudes of any art or science, partly from such historical facts as have reference to it, and, where facts are wanting, from inferences derived from considering what would be the most natural and probable conduct of mankind under the circumstances supposed.

4. *An Inquiry into the Nature and Causes of the Wealth of Nations*. The first edition was published at London in 1776, in two volumes 4to. The fourth edition, which was the last revised by the author, appeared in three volumes 8vo, in 1786.

5. *Essays on Philosophical Subjects*. Lond. 1795, 4to. These are the fragments which he exempted from the general destruction of his manuscripts, and which were published by his friends, Dr. Black and Dr. Hutton. In an advertisement prefixed to the publication, the editors state that, when the papers which Dr. Smith had left in their hands were examined, "the greater number appeared to be parts of a plan he once had formed for giving a connected history of the liberal sciences and elegant arts." "It is long," they add, "since he found it necessary to abandon that plan as far too extensive; and these parts of it lay beside him neglected until his death. The reader will find in them that happy connection, that full and accurate expression, and that clear illustration, which are conspicuous in the rest of his works; and though it is difficult to add much to the great fame he so justly acquired by his other writings, these will be read with satisfaction and pleasure." The papers in question comprise, I. fragments of a great work *On the Principles which lead and direct Philosophical Inquiries, illustrated* (1) *by the History of Astronomy*; (2) *by the History of the Ancient Physics*; and (3) *by the History of the Ancient Logics and Metaphysics*. II. An essay entitled, *Of the Nature of that Imitation which takes place in what are called the imitative Arts*. III. A short tract, *Of the Affinity between certain English and Italian Verses*. IV. A disquisition, *Of the External Senses*.

Of the historical dissertations, the first only, on the *History of Astronomy*, seems to be nearly complete. They are all written on the plan of the dissertation on the *Formation of Languages*, being partly theoretical and partly founded on fact. In the essay on the *History of Astronomy*,

Smithery
↓
Smoke.

after premising some acute and ingenious speculations with respect to the effects of unexpectedness and surprise, and of wonder and novelty, the author proceeds to give a brief, masterly, outline of the different astronomical systems, from the earliest ages down to that of Newton. The fragments that remain of the other two historical essays are much less complete, and do not possess the interest of the former. The short essay, *Of the Affinity between certain English and Italian Verses*, is curious rather than valuable. It affords a striking illustration of the variety and extent of Dr. Smith's literary pursuits. The disquisition with respect to the *External Senses* is of considerable extent. It embraces some ingenious discussions, and is a valuable contribution to the science of which it treats.

The *Wealth of Nations* has passed through many editions, some of which have been accompanied with notes and illustrations; but the best that has yet appeared, is that which was edited by Mr. M'Culloch, with notes and dissertations, embodying the views of later economists, and adapting the work to the present state of that science of which it has so eminently contributed to advance the progress.

SMITHERY, a smith's shop; also the art of a smith, by which iron is wrought into any shape by means of fire, hammering, and filing.

SMITING-LINE, in a ship, is a small rope fastened to the mizen-yard-arm, below at the deck, and is always furled up with the mizen-sail, even to the upper end of the yard, and thence it comes down to the poop. Its use is to loosen the mizen-sail without striking down the yard, which is easily done, because the mizen-sail is furled up only with rope-yarns; and therefore when this rope is pulled hard, it breaks all the rope-yarns, and so the sail falls down of itself. The sailor's phrase is, *smite the mizen*, that is, haul by this rope that the sail may fall down.

SMOAKY CAPE, on the east coast of New Holland. Long. 153. 42. Lat. 30. 55. S.

SMOKE, a dense elastic vapour arising from burning bodies. As this vapour is extremely disagreeable, and often prejudicial to health, several contrivances have been devised for the purpose of enabling us to enjoy the benefit of a fire without being annoyed by smoke; hence the use of chimneys, which, when properly constructed, carry it off entirely, but when improperly constructed, allow a part of it to escape into the room.

Chimneys operate in carrying off smoke by the rarity of the gaseous fluids which escape from the fire, and which, owing to their being expanded, are lighter than the adjoining air, and are therefore pressed up by it, carrying the smoke along with them. So long, then, as the gaseous products of the fire are lighter than the air, they ascend, while at the same time cold air must rush in from below to supply their place, which air, being heated in its turn, consumed, and mixed with the smoke, must also rise. The more, therefore, that the air in the chimney can be kept warm, so much the better; not only will the draught become greater, but there will also be less chance of any of the smoke being thrown back. The worse the power of the material of which the chimney is constructed for transmitting heat, the longer will the air within it be kept warm, and therefore the chimney will work better; hence the superior efficacy of bricks.

It is evident from what has been said, that there is a certain height to which chimneys may be carried, beyond which any farther lengthening, instead of being beneficial, will prove injurious; because, when the air within the chimney and without become of the same weight, which must be at a particular height in each, then if that chimney be made higher, the air within does not escape, or escapes slowly; air must therefore enter in slowly from below, and consequently the draught must be diminished. There are many circumstances which prevent chimneys

from working well, or in other words, which make them return a part of the smoke into the room.

The causes of the smoking of chimneys may be reduced to nine, differing from each other, and therefore requiring different remedies.

1. *Smoky chimneys in a new house are such frequently from mere want of air.* The workmanship of the rooms being all good, and just out of the workman's hands, the joints of the boards of the flooring, and of the panels of wainscoting, are all true and tight; the more so as the walls, perhaps not yet thoroughly dry, preserve a dampness in the air of the room which keeps the wood-work swelled and close. The doors and the sashes too, being worked with truth, shut with exactness, so that the room is as tight as a snuff-box, no passage being left open for air to enter except the key-hole, and even that is sometimes covered by a little dropping shutter. Now if smoke cannot rise but as connected with rarefied air, and a column of such air, suppose it filling the funnel, cannot rise unless other air be admitted to supply its place; and if therefore no current of air enter the opening of the chimney, there is nothing to prevent the smoke from being diffused in the room. If the motion upwards of the air in a chimney that is freely supplied be observed by the rising of the smoke or a feather in it, and it be considered that in the time such feather takes in rising from the fire to the top of the chimney, a column of air equal to the content of the funnel must be discharged, and an equal quantity supplied from the room below, it will appear absolutely impossible that this operation should go on if the tight room is kept shut; for were there any force capable of drawing constantly so much air out of it, it must soon be exhausted like the receiver of an air-pump, and no animal could live in it. Those therefore who stop every crevice in a room to prevent the admission of fresh air, and yet would have their chimney carry up the smoke, require inconsistencies, and expect impossibilities. Yet under this situation it is not uncommon to see the owner of a new house in despair, and ready to sell it for much less than it cost; conceiving it uninhabitable because not a chimney in any one of its rooms will carry off the smoke unless a door or window be left open. Much expense has also been incurred to alter and amend new chimneys which had really no fault. In one house particularly which Dr. Franklin knew that belonged to a nobleman in Westminster, that expense amounted to no less than L.300, after his house had been, as he thought, finished, and all charges paid. And after all, several of the alterations were ineffectual, for want of understanding the true principles.

Remedies. When you find on trial that opening the door or a window enables the chimney to carry up all the smoke, you may be sure that want of air from without is the cause of its smoking. "I say from *without*," adds Dr. Franklin, "to guard you against a common mistake of those who may tell you the room is large, contains abundance of air sufficient to supply any chimney, and therefore it cannot be that the chimney wants air. These reasoners are ignorant that the largeness of a room, if tight, is in this case of small importance, since it cannot part with a chimneyfull of its air without occasioning so much vacuum; which it requires a great force to effect, and could not be borne if effected."

It appearing plainly then, that some of the outward air must be admitted, the question will be, how much is absolutely necessary? for you would avoid admitting more, as being contrary to one of your intentions in having a fire, namely, that of warming your room. To discover this quantity, shut the door gradually while a middling fire is burning, till you find that before it is quite shut the smoke begins to come out into the room; then open it a little till you perceive the smoke comes out no longer. There hold the door, and observe the width of the open crevice between the edge of the door and the rabbet into which it should shut.

Smoke.

Smoke. Suppose the distance to be half an inch, and the door eight feet high; you thence find that your room requires an entrance for air equal in area to ninety-six half inches, or forty-eight square inches, or a passage of six inches by eight. This, however, is a large supposition, there being few chimneys that, having a moderate opening and a tolerable height of funnel, will not be satisfied with such a crevice of a quarter of an inch. Dr. Franklin found a square of six by six, or thirty-six square inches, to be a pretty good medium that will serve for most chimneys. High funnels with small and low openings may indeed be supplied through a less space; because, for reasons that will hereafter appear, the force of levity, if one may so speak, being greater in such funnels, the cool air enters the room with greater velocity, and consequently more enters in the same time. This, however, has its limits; for experience shews, that no increased velocity so occasioned has made the admission of air through the key-hole equal in quantity to that through an open door, though through the door the current moves slowly, and through the key-hole with great rapidity.

It remains then to be considered how and where this necessary quantity of air from without is to be admitted so as to be least inconvenient; for if at the door, left so much open, the air thence proceeds directly to the chimney, and in its way comes cold to your back and heels as you sit before your fire. If you keep the door shut, and raise a little the sash of your window, you feel a similar inconvenience. Various have been the contrivances to avoid this, such as bringing in fresh air through pipes in the jams of the chimney, which pointing upwards should blow the smoke up the funnel; opening passages in the funnel above, to admit air for the same purpose. But these produce an effect contrary to that intended; for as it is the constant current of air passing from the room through the opening of the chimney into the funnel which prevents the smoke from coming out into the room, if you supply the funnel by other means or in other ways with the air which it requires, and especially if that air be cold, you diminish the force of that current, and the smoke in its efforts to enter the room finds less resistance.

The required air must then indispensably be admitted into the room, to supply what goes off through the opening of the chimney. M. Gauger, a very ingenious and intelligent French writer on the subject, proposes with judgment to admit it above the opening of the chimney; and to prevent inconvenience from its coldness, he directs that it may be so made, that it shall pass in its entrance through winding cavities made behind the iron back and sides of the fire-place, and under the iron hearth-plate; in which cavities it will be warmed, and even heated, so as to contribute much, instead of cooling, to the warming of the room. This invention is excellent in itself, and may be used with advantage in building new houses, because the chimneys may then be so disposed as to admit conveniently the cold air to enter such passages. But in houses built without such views, the chimneys are often so situated as not to afford that convenience without great and expensive alterations. Easy and cheap methods, though not quite so perfect in themselves, are of more general utility; and such are the following.

In all rooms where there is a fire, the body of air warmed and rarefied before the chimney is continually changing place, and making room for other air that is to be warmed in its turn. Part of it enters and goes up the chimney, and the rest rises and takes place near the ceiling. If the room be lofty, that warm air remains above our heads as long as it continues warm, and we are little benefited by it, because it does not descend till it is cooler. Few can imagine the difference of climate between the upper and lower parts of such a room, who have not tried it by the thermometer, or by going up a ladder till their heads are near the ceiling. It is then among this warm air that the requisite quantity of

outward air is best admitted, with which being mixed, its coldness is abated, and its inconvenience diminished so as to become scarcely observable. This may be easily done by drawing down about an inch the upper sash of a window; or, if not moveable, by cutting such a crevice through its frame; in both which cases it will be well to place a thin shelf of the length to conceal the opening, and sloping upwards, to direct the entering air horizontally along and under the ceiling. In some houses the air may be admitted by such a crevice made in the wainscot, cornice, or plastering, near the ceiling and over the opening of the chimney. This, if practicable, is to be chosen, because the entering cold air will there meet with the warmest rising air from before the fire, and be soonest tempered by the mixture. The same kind of shelf should also be placed here. Another way, and not a very difficult one, is to take out an upper pane of glass in one of your sashes, set it in a tin frame, giving it two springing angular sides, and then replacing it, with hinges below, on which it may be turned to open more or less above. It will then have the appearance of an internal sky-light. By drawing this pane in, more or less, you may admit what air you find necessary. Its position will naturally throw that air up and along the ceiling. In England some have of late years cut a round hole about five inches diameter in a pane of the sash, and placed against it a circular plate of tin hung on an axis, and cut into vanes; which, being separately bent a little obliquely, are acted upon by the entering air, so as to force the plate continually round like the vanes of a windmill. This admits the outward air, and by the continual whirling of the vanes, does in some degree disperse it. The noise only is a little inconvenient.

2. A second cause of the smoking of chimneys is, *their openings in the room being too large*; that is, too wide, too high, or both. Architects in general have no other ideas of proportion in the opening of a chimney than what relate to symmetry and beauty respecting the dimensions of the room; while its true proportion respecting its function and utility depends on quite other principles; and they might as properly proportion the step in a staircase to the height of the storey, instead of the natural elevation of men's legs in mounting. The proportion then to be regarded, is what relates to the height of the funnel. For as the funnels in the different storeys of a house are necessarily of different heights or lengths, that from the lowest floor being the highest or longest, and those of the other floors shorter and shorter, till we come to those in the garrets, which are of course the shortest; and the force of draft being, as already said, in proportion to the height of funnel filled with rarefied air, and a current of air from the room into the chimney, sufficient to fill the opening, being necessary to oppose and prevent the smoke from coming out into the room; it follows, that the openings of the longest funnels may be larger, and that those of the shorter funnels should be smaller. For if there be a larger opening to a chimney that does not draw strongly, the funnel may happen to be furnished with the air which it demands by a partial current entering on one side of the opening, and leaving the other side free of any opposing current, may permit the smoke to issue there into the room. Much, too, of the force of draft in a funnel depends on the degree of rarefaction in the air it contains, and that depends on the nearness to the fire of its passage in entering the funnel. If it can enter far from the fire on each side, or far above the fire, in a wide or high opening, it receives little heat in passing by the fire, and the contents of the funnel are by those means less different in levity from the surrounding atmosphere, and its force in drawing consequently weaker. Hence, if too large an opening be given to chimneys in upper rooms, those rooms will be smoky. On the other hand, if too small openings be given to chimneys in the lower rooms,

Smoke. the entering air operating too directly and violently on the fire, and afterwards strengthening the draft as it ascends the funnel, will consume the fuel too rapidly.

Remedy. As different circumstances frequently mix themselves in these matters, it is difficult to give precise dimensions for the openings of all chimneys. Our fathers made them generally much too large. We have lessened them; but still they are often of greater dimensions than they should be, the human eye not being easily reconciled to sudden and great changes. If you suspect that your chimney smokes from the too great dimensions of its opening, contract it by placing moveable boards, so as to lower and narrow it gradually, till you find the smoke no longer issues into the room. The proportion so found will be that which is proper for that chimney, and you may employ the bricklayer or mason to reduce it accordingly. However, as in building new houses something must be sometimes hazarded, Dr. Franklin proposes to make the openings in the lower rooms about thirty inches square, and eighteen deep, and those in the upper only eighteen inches square, and not quite so deep; the intermediate ones diminishing in proportion as the height of the funnel is diminished. In the larger openings, billets of two feet long, or half the common length of cordwood, may be burned conveniently; and for the smaller, such wood may be sawed into thirds. Where coals are the fuel, the grates will be proportioned to the openings. The same depth is nearly necessary to all, the funnels being all made of a size proper to admit a chimney-sweeper. If in large and elegant rooms custom or fancy should require the appearance of a larger chimney, it may be formed of expensive marginal decorations, in marble, or in any thing else. But in time, perhaps, that which is fittest in the nature of things may come to be thought handsomest.

3. Another cause of smoky chimneys is *too short a funnel*. This necessarily happens in some cases, as where a chimney is required in a low building; for, if the funnel be raised high above the roof, in order to strengthen its draft, it is then in danger of being blown down, and crushing the roof in its fall.

Remedies. Contract the opening of the chimney, so as to oblige all the entering air to pass through or very near the fire; whereby it will be more heated and rarefied, the funnel itself be more warmed, and its contents have more of what may be called the force of levity, so as to rise strongly and maintain a good draft at the opening.

Or you may in some cases, to advantage, raise additional storeys over the low building, which will support a high funnel. If the low building be used as a kitchen, and a contraction of the opening therefore inconvenient, a large one being necessary, at least when there are great dinners, for the free management of so many cooking utensils; in such cases the best expedient perhaps would be to build two more funnels joining to the first, and having three moderate openings, one to each funnel, instead of one large one. When there is occasion to use but one, the other two may be kept shut by sliding plates, hereafter to be described; and two or all of them may be used together when wanted. This will indeed be an expense, but not an useless one, since your cooks will work with more comfort, see better than in a smoky kitchen what they are about, your victuals will be cleaner dressed, and not taste of smoke, as is often the case; and to render the effect more certain, a stack of three funnels may be safely built higher above the roof than a single funnel.

The case of too short a funnel is more general than would be imagined, and often found where one would not expect. For it is not uncommon, in ill-contrived buildings, instead of having a funnel for each room or fire-place, to bend and turn the funnel of an upper room, so as to make it enter the side of another funnel that comes from

below. By these means the upper room funnel is made short of course, since its length can only be reckoned from the place where it enters the lower room funnel; and that funnel is also shortened by all the distance between the entrance of the second funnel and the top of the stack; for all that part being readily supplied with air through the second funnel, adds no strength to the draft, especially as that air is cold when there is no fire in the second chimney. The only easy remedy here is, to keep the opening of that funnel shut in which there is no fire.

4. Another very common cause of the smoking of chimneys is, *their overpowering one another*. For instance, if there be two chimneys in one large room, and you make fires in both of them, with doors and windows close shut, you will find that the greater and stronger fire shall overpower the weaker, from the funnel of which it will draw down air to supply its own demand; which air descending in the weaker funnel, will drive down its smoke, and force it into the room. If, instead of being in one room, the two chimneys are in two different rooms, communicating by a door, the case is the same whenever that door is open. In a very tight house, a kitchen chimney on the lowest floor, when it had a great fire in it, has been known to overpower any other chimney in the house, and draw air and smoke into its room as often as the door communicating with the staircase was opened.

Remedy. Take care that every room have the means of supplying itself from without with the air which its chimney may require, so that no one of them may be obliged to borrow from another, nor under the necessity of lending. A variety of these means has been already described.

5. Another cause of smoking is, *when the tops of chimneys are commanded by higher buildings, or by a hill*, so that the wind blowing over such eminences falls like water over a dam, sometimes almost perpendicularly on the tops of the chimneys that lie in its way, and beats down the smoke contained in them.

Remedy. That commonly applied in this case is a turncap made of tin or plate iron, covering the chimney above and on three sides, open on one side, turning on a spindle; and which, being guided or governed by a vane, always presents its back to the current. This may be generally effectual, though not certain, as there may be cases in which it will not succeed. Raising your funnels, if practicable, so as their tops may be higher, or at least equal, with the commanding eminence, is more to be depended on. But the turning-cap, being easier and cheaper, should first be tried. "If obliged to build in such a situation, I would choose," says Dr. Franklin, "to place my doors on the side next the hill, and the backs of my chimneys on the farthest side; for then the column of air falling over the eminence, and of course pressing on that below, and forcing it to enter the doors on that side, would tend to balance the pressure down the chimneys, and leave the funnels more free in the exercise of their functions."

6. There is another case which is the reverse of that last mentioned. It is where the commanding eminence is farther from the wind than the chimney commanded.

Remedy. There is but one remedy, which is to raise such a funnel higher than the roof, supporting it if necessary by iron bars. For a turncap in this case has no effect, the dammed-up air pressing down through it in whatever position the wind may have placed its opening.

Dr. Franklin mentions a city in which many houses are rendered smoky by this operation. For their kitchens being built behind, and connected by a passage with the houses, and the tops of the kitchen chimneys lower than the tops of the houses, the whole side of a street when the wind blows against its back, forms such a dam as above described; and the wind so obstructed forces down those kitchen chimneys, especially when they have but weak fires in them, to pass

Smoke. through the passage and house into the street. Kitchen-chimneys so formed and situated have another inconvenience. In summer, if you open your upper-room windows for air, a light breeze blowing over your kitchen chimney towards the house, though not strong enough to force down its smoke as aforesaid, is sufficient to waft it into your windows, and fill the rooms with it, which, besides the disagreeableness, damages your furniture.

7. Chimneys, otherwise drawing well, are sometimes made to smoke by *the improper and inconvenient situation of a door*. When the door and chimney are on the same side of the room, if the door being in the corner is made to open against the wall, which is common, as being there, when open, more out of the way, it follows, that when the door is only opened in part, a current of air rushing in passes along the wall into and across the opening of the chimney, and flirts some of the smoke out into the room. This happens more certainly when the door is shutting, for then the force of the current is augmented, and becomes very inconvenient to those who, warming themselves by the fire, happen to sit in its way.

The *remedies* are obvious and easy. Either put an intervening screen, from the wall round great part of the fireplace; or, which is perhaps preferable, shift the hinges of your door, so that it may open the other way, and when open, throw the air along the other wall.

8. A room that has no fire in its chimney is sometimes filled with *smoke which is received at the top of its funnel and descends into the room*. Funnels without fires have an effect according to their degree of coldness or warmth on the air that happens to be contained in them. The surrounding atmosphere is frequently changing its temperature; but stacks of funnels covered from winds and sun by the house that contains them, retain a more equal temperature. If, after a warm season, the outward air suddenly grows cold, the empty warm funnels begin to draw strongly upwards; that is, they rarefy the air contained in them, which of course rises, cooler air enters below to supply its place, is rarefied in its turn, and rises; and this operation continues till the funnel grows cooler, or the outward air warmer, or both, when the motion ceases. On the other hand, if after a cold season the outward air suddenly grows warm, and of course lighter, the air contained in the cool funnels, being heavier, descends into the room; and the warmer air which enters their tops being cooled in its turn, and made heavier, continues to descend; and this operation goes on till the funnels are warmed by the passing of warm air through them, or the air itself grows cooler. When the temperature of the air and of the funnels is nearly equal, the difference of warmth in the air between day and night is sufficient to produce these currents. The air will begin to ascend the funnels as the cool of the evening comes on, and this current will continue till perhaps nine or ten o'clock next morning, when it begins to hesitate; and as the heat of the day approaches, it sets downwards, and continues so till towards evening, when it again hesitates for some time, and then goes upwards constantly during the night, as before mentioned. Now when smoke issuing from the tops of neighbouring funnels passes over the tops of funnels which are at the time drawing downwards, as they often are in the middle part of the day, such smoke is of necessity drawn into these funnels, and descends with the air into the chamber.

The remedy is to have a sliding plate that will perfectly shut the offending funnel. Dr. Franklin has thus described it. "The opening of the chimney is contracted by brick-work faced with marble slabs to about two feet between the jams, and the breast brought down to within about three feet of the hearth. An iron frame is placed just under the breast, and extending quite to the back of the chimney, so that a plate of the same metal may slide horizontally backwards

and forwards in the grooves on each side of the frame. This plate is just so large as to fill the whole space, and shut the chimney entirely when thrust quite in, which is convenient when there is no fire. Draw it out, so as to leave between its further edge and the back a space of about two inches; this space is sufficient for the smoke to pass; and so large a part of the funnel being stopped by the rest of the plate, the passage of warm air out of the room, up the chimney, is obstructed and retarded; and by those means much cold air is prevented from coming in through crevices, to supply its place. This effect is made manifest three ways. 1. When the fire burns briskly in cold weather, the howling or whistling noise made by the wind, as it enters the room through the crevices, when the chimney is open as usual, ceases as soon as the plate is slid in to its proper distance. 2. Opening the door of the room about half an inch, and holding your hand against the opening, near the top of the door, you feel the cold air coming in against your hand, but weakly, if the plate be in. Let another person suddenly draw it out, so as to let the air of the room go up the chimney, with its usual freedom where chimneys are open, and you immediately feel the cold air rushing in strongly. 3. If something be set against the door, just sufficient, when the plate is in, to keep the door nearly shut, by resisting the pressure of the air that would force it open; then, when the plate is drawn out, the door will be forced open by the increased pressure of the outward cold air endeavouring to get in to supply the place of the warm air that now passes out of the room to go up the chimney. In our common open chimneys, half the fuel is wasted, and its effect lost; the air it has warmed being immediately drawn off."

9. Chimneys which generally draw well, do nevertheless sometimes give smoke into the rooms, *it being driven down by strong winds passing over the tops of their funnels*, though not descending from any commanding eminence. This case is most frequent where the funnel is short, and the opening turned from the wind. It is the more grievous, when it happens to be a cold wind that produces the effect, because when you most want your fire you are sometimes obliged to extinguish it. To understand this, it may be considered that the rising light air, to obtain a free issue from the funnel, must push out of its way or oblige the air that is over it to rise. In a time of calm or of little wind this is done visibly; for we see the smoke that is brought up by that air rise in a column above the chimney. But when a violent current of air, that is, a strong wind, passes over the top of a chimney, its particles have received so much force which keeps them in a horizontal direction, and follow each other so rapidly, that the rising light air has not strength sufficient to oblige them to quit that direction and move upwards to permit its issue.

Remedies. In Venice, the custom is to open or widen the top of the flue, rounding it in the true form of a funnel. In other places the contrary is practised; the tops of the flues being narrowed inwards, so as to form a slit for the issue of the smoke, as long as the breadth of the funnel, and only four inches wide. This seems to have been contrived on a supposition that the entry of the wind would thereby be obstructed; and perhaps it might have been imagined, that the whole force of the rising warm air being condensed, as it were, in the narrow opening, would thereby be strengthened, so as to overcome the resistance of wind. This, however, did not always succeed; for when the wind was at north-east and blew fresh, the smoke was forced down by fits into the room where Dr. Franklin commonly sat, so as to oblige him to shift the fire into another. The position of the slit of this funnel was indeed north-east and south-west. Perhaps if it had lain across the wind, the effect might have been different. But on this we can give no certainty. It seems a matter proper to be referred to experi-

Smoke.

Smoke. ment. Possibly a turncap might have been serviceable, but it was not tried.

With all the science, however, that a man shall suppose himself possessed of in this article, he may sometimes meet with cases that shall puzzle him. "I once lodged," says Dr. Franklin, "in a house at London, which in a little room had a single chimney and funnel. The opening was very small, yet it did not keep in the smoke, and all attempts to have a fire in this room were fruitless. I could not imagine the reason, till at length observing that the chamber over it, which had no fireplace in it, was always filled with smoke when a fire was kindled below, and that the smoke came through the cracks and crevices of the wainscoat, I had the wainscoat taken down, and discovered that the funnel which went up behind it had a crack many feet in length, and wide enough to admit my arm; a breach very dangerous with regard to fire, and occasioned probably by an apparent irregular settling of one side of the house. The air entering this breach freely, destroyed the drawing force of the funnel. The remedy would have been, filling up the breach, or rather rebuilding the funnel; but the landlord rather chose to stop up the chimney.

"Another puzzling case I met with at a friend's country-house near London. His best room had a chimney in which, he told me, he never could have a fire, for all the smoke came out into the room. I flattered myself I could easily find the cause and prescribe the cure. I opened the door, and perceived it was not want of air. I made a temporary contraction of the opening of the chimney, and found that it was not its being too large that caused the smoke to issue. I went out and looked up at the top of the chimney: Its funnel was joined in the same stack with others, some of them shorter, that drew very well, and I saw nothing to prevent its doing the same. In fine, after every other examination I could think of, I was obliged to own the insufficiency of my skill. But my friend, who made no pretension to such kind of knowledge, afterwards discovered the cause himself. He got to the top of the funnel by a ladder, and looking down found it filled with twigs and straw cemented by earth and lined with feathers. It seems the house, after being built, had stood empty some years before he occupied it; and he concluded that some large birds had taken the advantage of its retired situation to make their nests there. The rubbish, considerable in quantity, being removed, and the funnel cleared, the chimney drew well, and gave satisfaction."

Chimneys whose funnels go up in the north wall of a house, and are exposed to the north winds, are not so apt to draw well as those in a south wall; because, when rendered cold by those winds, they draw downwards. Chimneys enclosed in the body of a house are better than those whose funnels are exposed in cold walls. Chimneys in stacks are apt to draw better than separate funnels, because the funnels that have constant fires in them warm the others in some degree that have none.

SMOKE-consuming. In manufacturing towns, where a great deal of fuel is used, it is of the utmost consequence to prevent, if possible, the production of smoke, so as not only to get quit of a great source of annoyance, but also to prevent the injury which it occasions to buildings; indeed to prevent the deterioration of property which in general occurs. Hence the clauses in acts of Parliament and in many police bills, compelling proprietors of steam engines, &c., to consume their smoke, if practicable; as also the numerous attempts which have been made to accomplish this object. Of course, if it could be done without an extra expenditure of fuel, so much the better; if with a saving of fuel, then the advantages to be gained are immense.

Numerous methods have been recommended, and many patents have been secured for accomplishing this desirable

object. The principle of most of them depends on causing the smoke, immediately when given off from the coal, when fresh put on the fire, to pass over the half-burned or charred fuel, and thus be consumed.

Smoke is merely carbonaceous matter evolved from fuel; for when the whole of the inflammable gaseous product is not brought into contact with air at a proper degree of heat, it is not burned, and therefore escapes in the state of smoke. Now it is evident, that if that smoke or carbonaceous particles, as it flows over the burning fuel, be supplied with air, it also will be burned, provided they are brought together at a high temperature; but this is not done in the usual way of combustion, because the air passing up from the ash pit through the fuel, is almost entirely deprived of its oxygen before it reaches the upper part of the furnace. In addition to the air, therefore, which is requisite for the combustion of the fuel, air must also be admitted *above the fire* for the consumption of the smoke.

The most common method in practice for consuming smoke is, instead of throwing the fuel back into the furnace, to place it always on the dead plate or charring plate at the mouth, gradually pushing it on upon the bars, as it is charred, or deprived of its bituminous principle, and again supplying more on the dead plate, which is in general inclined, so as to allow the fuel placed on it to fall, and come into contact with that on the bars. For the success of this process, air must be admitted into the furnace, above the fuel, so as to mix with the flame and smoke; but this is attended with disadvantage, for being cold, it not only acts injuriously, as in lessening the production of steam, but by bringing down the temperature, prevents the action on the smoke itself, which is consequently not all destroyed. Hence the practice of heating the air to be thus admitted. When this is done by an additional fire, though the smoke may to a certain extent be consumed, yet it is attended with expense; but this is obviated in a great measure by the introduction of tubes into the flues or chimney, one end communicating with the atmosphere, the other terminating in the furnace, over the fuel, by which the air that passes through them derives a part of that heat which is otherwise carried up the vent.

This method of preventing smoke has not been attended with the success at first expected from it, as is proved by its not having come into general use. Perhaps one source of failure is the difficulty of getting the firemen to supply the coal carefully on the front of the furnace; and hence it has been recommended to employ hoppers, by which the coal is always thrown on the dead-plate; but even when these are used, the consumption of smoke is not complete. As to the heating of the air, by passing it through tubes in the chimney or vent, one great objection to them is the powerful influence they have over the draught. It is well known, that when cold air is allowed to rush into the chimney, the draught is instantly diminished. Now these tubes must operate in the same way; for though the air does not mingle with that in the vent, yet by withdrawing heat from it, it must reduce its temperature, and thus prevent it from being forced up.

By far the most effectual method of consuming smoke is that lately recommended and patented by Ivison. It consists in throwing steam into the fore-part of the furnace, *above the fuel*, by means of a fan-shaped distributor, in the front of which are small apertures, varying in size and number, according to the width of the furnace and the pressure of the steam. In general they are from five to eight or ten in number, and about an eighth or a twelfth of an inch in diameter. The quantity of steam thus admitted is very trifling; and by its passage through the flame and smoke given off from the coals on the charring-plate, it instantly causes the disappearance of the smoke, and accordingly none whatever escapes from the chimney-top, except just when

Smoke.

Smoke. fresh coal is thrown in, and then it is barely perceptible, and only for a few seconds.

When applied to furnaces with boilers, steam is easily procured, by taking from the top of the boiler a small tube, which is carried into the furnace, and connected with the distributor, and by means of a stop-cock the supply is regulated. In cases where there is no boiler, a very small one must be erected, which can be placed on some part of the furnace, and will thus give off steam without any extra expenditure of fuel.

The most remarkable circumstance attending the use of this patent process, is the almost total absence of draught through the ash-pit, consequently little or no air passes up through the fire, while there is a rush of air *over the surface of the fuel*. Hence the necessity of allowing air to flow in by the door of the furnace, or, which is better, by means of tubes placed in the chimney or flues, by which it is heated previous to its entrance; because, as before stated, the admission of cold air must have a prejudicial effect. It is evident from this, that the combustion must proceed almost entirely by air supplied on the surface. Indeed, when properly applied, the supply of air through the ash-pit is almost reduced to nothing; and accordingly the fire can be kept in good condition, even though the ash-pit is closed in front.

In addition to the consumption of smoke, the application of steam in this way is attended with another advantage; the saving of fuel, which is certainly a great recommenda-

tion in its favour. Different statements have been given of the amount of saving effected; but if we can place reliance in the reports given by the patentee, it seems to be considerable.

Watt, from his numerous experiments, concluded, that for each pound of coal (English caking) consumed, rather more than eight pounds of water could be evaporated, thus requiring about eight pounds of coal for the cubic foot of water. Since his time, however, improvements in the construction of furnaces have been introduced, which have increased the amount of evaporation.

Mr. Watt's maximum result with Wallsend caking coal, conducted with the greatest care, was 8.9 pound of water to the pound of coal. The lowest was 5.93, the mean 7.4.

Mr. Parkes of Warwick states the ordinary result with one pound of caking coal to be 7.5 pounds, evaporated from 212°, but by his improved method in the furnaces of other persons, it was 8.7, while by a similar mode with his own furnace, it was 10.32 pounds.

With one of the Cornish boilers, coated and covered with the greatest care, and in all other respects rendered as perfect as possible, the result was 11.8 pounds, and a similar result was more recently obtained by Henwood.

The following is a tabular view of the results of Watt and others, shewing the quantity of water evaporated, and the quantity of fuel required for the horse-power of an engine:

EXPERIMENTS.	lbs. water to 1 lb. of English coal.	lbs. English coal to cubic foot water, or horse- power per hour.	Cubic feet of water to 84 lb. English coal.	Cubic feet water to 112 lb. English coal.
Watt's average,.....	7.4	8.4	10.	13.33
United Mines Loam (Ed. Phil Jour., July 1839),...	9.58	6.23	12.93	17.24
Parkes of Warwick's method,.....	10.32	6.03	13.9	18.5
Huel Towan (Ed. Phil. Jour., July 1839),.....	10.55	5.9	14.23	18.97
Mr. Henwood's experiment,.....	11.87	5.32	15.8	21.

By the use of the Ivison patent, when properly applied, the amount of evaporation becomes much greater, as has been certified by repeated trials, by scientific men of eminence, as the following table shews. The experiments were conducted with Scottish coal; and considering the

heat given out by it, as compared to English caking coal, to be as three to four, the results will shew the amount of evaporation, or, which is the same thing, the quantity of fuel, used in comparison with what is given in the preceding table.

EXPERIMENTS.	lbs. water to 1 lb. of <i>Scottish</i> coal.	lbs. water to 1 lb. of English coal.	lbs. English coal to cubic foot water, or horse- power per hour.	Cubic feet of water to 84 lb. English coal.	Cubic feet water to 112 lb. English coal.
Average of 8 experiments, certified } April 13, 1839,.....	11.41	15.21	4.09	20.5	27.4
Average of 3 experiments, certified } May 10, 1839,.....	13.94	18.58	3.35	25.	33.46
Average of 12 workings, certified } July 1839,.....	13.25	17.66	3.52	23.91	31.78
Maximum result of do.,.....	14.72	19.62	3.12	26.47	35.3
Average of the four preceding lines,.	13.43	17.96	3.46	24.02	32.3

From the above tables it appears, that the greatest quantity of water evaporated by the pound of English coal is 11.37; the maximum result by Ivison's process is, using Scottish coal, 14.72; the average 13.43; which, if we consider the English to the Scottish as four to three, gives 17.9, or equal to only about 3.46 of English coal to the cubic foot

of water or horse power of an engine, certainly by far the largest and most economical result on record.

That this mode of consuming smoke is accompanied with saving of fuel, is also proved by comparative trials made with and without the use of steam, on the same furnace, as is shewn by the following table:

Smoke.

Smoke
||
Smollett.

Workings with the Patent.				Workings without the Patent.			
Date.	Time.	Period of day.	Pounds of Coal used.	Date.	Time.	Period of day.	Pounds of Coal used.
Sept. 25, 1838.	5 h. 15 m.	P.M.	560	Sept. 25, 1838.	5 h. 15 m.	A.M.	812
— 26, —	5 — 15 —	A.M.	449	— 26, —	5 — 15 —	P.M.	812
— 27, —	5 — 15 —	A.M.	612	— 27, —	5 — 15 —	P.M.	812
Average,.....558				Average,.....812			

For the same time, then, and for the same amount of work done, the consumpt of fuel, as shewn by the above table, is in the ratio of 812 to 540, or as 100 to 66, thus indicating a saving of about 33 per cent.

By the admission of steam into the furnace in this way of consuming smoke, the draught is prodigiously increased; hence the absolute necessity, when applied to furnaces having tall chimneys, of resorting to means to counteract it. It is remarkable that the damper in common use has comparatively little or no effect. The means found to answer best are the admission of cold air into the chimney, by apertures, which can be varied in size, according to circumstances; or when this is found not to be sufficient, to have covers to the ash-pit, by which the draught up through the bars may be prevented; for it is only when the draught is properly checked, and a due quantity of air admitted above the fuel, that none flows into the ash-pit. In furnaces to be erected for the purpose, the draught can be sufficiently checked, by making the chimney much narrower and shorter than those now in use. In fact, were it not for the necessity of having a vent to carry off the gaseous products, the chimney might be dispensed with, as the steam of itself creates sufficient draught to carry in air for the combustion. Hence one very great advantage, in addition to the many others, to be derived from this mode; as, independently of economy in fuel, there must be an immense saving in the outlay in constructing furnaces; the application of the steam-tube with its distributor costing very little.

Different opinions are entertained with regard to the *rationale* of this process. Some suppose that the steam merely acts mechanically, by carrying along with it a sufficient quantity of air to maintain the combustion; and that that air flowing *over* the fuel, not only carries on its consumption there, but, acting on the smoke, causes its combustion also, by which of course there is an additional supply of heat. Besides, as the upper part of the furnace is free from smoke, the radiation from the fire must have a more powerful effect on the bottom of the boiler, and those parts of it exposed in the flues being also free from soot, will more easily transmit the heat. If, however, we place reliance on the results of the trials stated above, and the names of the scientific gentlemen by whom they were conducted is a proof of their accuracy, it is difficult to conceive how so large a result should be obtained, were there no further action than the consumption of the fuel. It is generally admitted, that were the whole of the heat from coal undergoing combustion rendered available, about fourteen pounds of water would be evaporated on an average by each pound of coal. But this cannot be done, because part of the heat must necessarily pass off by the chimney; but even with this waste, the quantity of water evaporated by Scottish coal was in some trials beyond fourteen pounds. This has given rise to the idea, that the steam, in addition to its mechanical action of carrying air into the upper part of the furnace, acts also chemically, that in fact it is decomposed and consumed. It has been long known, that when steam is passed through tubes stuffed with incandescent carbon, it is decomposed, and resolved into gaseous products. In a paper published by Dr. Fyfe in the *Edinburgh Phil. Jour-*

VOL XX.

nal, 1837, it is shewn, that these gaseous products are not carbonic acid and carburetted hydrogen, as at one time supposed, but carbonic oxid and pure hydrogen. Now a similar decomposition may be effected on the steam in the Ivison process; for when it is brought into contact with the carbonaceous matter of the smoke, as given off at a high temperature from the coal on the charring-plate, it may be decomposed, and give, by its action on the smoke, carbonic oxid and hydrogen; and these being freely supplied with air, will be burned, and by their combustion give out an additional supply of heat, and it is well known that the heat given forth by hydrogen is very great. If this explanation be the correct one, (and it is strengthened by the fact, that when the coal is thrown far back in the furnace, so as to be beyond the influence of the steam, it is not consumed), then the smoke is not burned by the direct action of the air, but by first getting oxygen from the steam, so as to form carbonic oxid, and which oxid then receives oxygen from the atmosphere. An additional quantity of oxygen is thus required; and hence most probably the additional amount of heat evolved by the process. (D. H.)

SMOKE-Silver. Lands were held in some places by the payment of the sum of sixpence yearly to the sheriff, called *smoke-silver* (Par. 4. Edw. VI.) Smoke-silver and smoke-penny are to be paid to the ministers of divers parishes as a *modus* in lieu of tithe-wood; and in some manors formerly belonging to religious houses, there is still paid, as appended to the said manors, the ancient Peter-pence, by the name of *Smoke money*. (Twisd. *Hist. Vindicat.* 77.)

SMOLENSKO, a circle or government of the eastern side of the Russian empire. It was formerly a part of Lithuania, and being gained by Russia in 1654, was then called White Russia. It is 10,980 square miles in extent, and contains 1,031,860 inhabitants, who are a mixture of Russians, Poles, and Jews. The city from which the province takes its name, stands in a valley, watered by the river Dnieper, which runs from east to west, and which is navigable for barges. The city, which has been rebuilt since the war, is now said to contain 15,000 inhabitants. For this population there are upwards of twenty churches. It has a cathedral for both Catholic and Greek Christians, an ecclesiastical seminary, and a gymnasium or high grammar school. It is a frontier and fortified town, and is remarkable for the great battle fought under the walls of the city, on the 16th of August 1812.

SMOLLETT, *TOBIAS*, whose writings have conferred distinguished honour upon the literature of his country, was descended from a family of considerable antiquity and opulence in the county of Dunbarton. His grandfather, Sir James Smollett of Bonhill, married a daughter of Sir Aulay Macaulay of Ardincaple, and by that lady had four sons, of whom Archibald, the youngest, was the father of the novelist. Archibald, who had been bred to no profession, died at an early age, leaving his family, consisting of a widow and three children, one of whom was an infant daughter, solely dependent on the bounty of his father. Smollett was born in 1721, in the old mansion-house of Dulquhurn, now a ruin. It is situated near the village of Renton, in the parish of Cardross. He was baptized Tobias George. The

3 H

Smollett. valley of the Leven, in which Smollett first saw the light, is surpassed by no other spot in our island, either for the grandeur of its scenery, or for the venerable associations with which it is connected. Nor was the ground which had been dignified by the tread of Wallace, Bruce, Napier, and Buchanan, dishonoured by the steps of Smollett.

From the grammar-school of Dunbarton, in which he had imbibed the rudiments of classical learning, Smollett was transferred to the University of Glasgow, where he prosecuted his more advanced studies with application and success. He was afterwards bound an apprentice to Mr. John Gordon, an eminent medical practitioner in that city. His elder brother James had adopted the profession of arms, an example which he was ambitious of following; but the old knight probably illustrated the advantages of the study of physic by reasoning which it would have been vain to controvert. When the young student had attained his eighteenth year, his grandfather died, without having made any adequate provision for the children of his youngest son. For this omission, his descendant furnished him with a niche in *Roderick Random*, more conspicuous than desirable.

The term of his apprenticeship having expired in his nineteenth year, and being now thrown upon his own resources, Smollett proceeded to London, where he attracted the notice of Lord Lyttelton. He had carried with him his tragedy of *The Regicide*, a juvenile performance of uncommon merit, but indifferently adapted to the purpose of representation. The various efforts which he ineffectually used to bring his play upon the stage, are detailed with indignant prolixity in the preface to that production, which he sent to the press some years afterwards, with a view of heaping confusion upon the lukewarm patronage of Lyttelton, and upon the shuffling evasions of Garrick. The patron and the manager were visited with many other tokens of his displeasure; but he lived to repent of the severe retribution which he had exacted for trivial wrongs, and made honourable mention of both in his *History of England*.

Thwarted in his expectations of earning fame and profit as a writer for the stage, Smollett was glad to accept the situation of surgeon's mate on board the *Cumberland*. That vessel, an eighty-gun ship, belonged to the armament which was bound to the West Indies, to join the fleet under the command of Admiral Vernon. Of the disastrous expedition against Carthage, Smollett inserted an animated narrative in *Roderick Random*, and afterwards published a more detailed account in the *Compendium of Voyages*. When the discomfited squadrons returned to Jamaica, he quitted the service in disgust, and fixed his residence on the island. With Miss Lascelles, a fascinating West Indian, he there formed an acquaintance, which afterwards ripened into a matrimonial union. In 1746 he returned to London, which then resounded with acclamations occasioned by the victory at Culloden. With these were mingled some expressions of indignation at the atrocities inflicted by the royal army upon the helpless families of the insurgents. The voice of Smollett swelled the weaker cry, and he produced his pathetic ode, *The Tears of Scotland*. During the same year was published, *Advice, a Satire*. His next literary effort was *Alceste, an Opera*, which he wrote at the suggestion of Mr. Rich of Covent Garden Theatre. In consequence of some dispute with that patentee, the piece was withdrawn, and has never appeared in print. In 1747 he published *Reproof*, a second part of his former satirical production. The versification of these poems is sufficiently harmonious, and they abound with impetuous

invective; but the rage of the satirist is without dignity, and rabid, without being infectious to readers of the present day. About this period he married Miss Lascelles, who was possessed of a small estate in the island of Jamaica; a precarious species of property, from which her husband appears to have derived little or no ultimate benefit.

In the year 1748, appeared *The Adventures of Roderick Random*. Fielding had already evinced himself a noble follower of Cervantes, and Smollett now stood forth, a no less worthy disciple of Le Sage. It must be owned that in this, and in all the other novels of Smollett, humour frequently appears in very loose attire. These scenes, however, like sheet-lightning, are alarming, but perfectly innocuous. The solemn depravity of Rousseau is more dangerous than the ludicrous indecorum of Smollett. In 1749, *The Regicide* was published by subscription. During the same year Smollett took the degree of M.D., in what University has not been ascertained. In 1750 he went to Paris, where he is supposed to have occupied himself in composing *The Adventures of Peregrine Pickle*, which were published in 1751. This admirable novel is disfigured by the introduction of an impertinent episode, in which are detailed, with unrelenting minuteness, the tedious intrigues of Lady Vane; who is said to have rewarded Smollett handsomely for the drudgery of compiling that durable record of her infamy. To compensate for this blemish, and for some rash sallies of humour, *Peregrine Pickle* is an absolute mine of character and adventure. The entertainment prepared by the learned physician, in the manner of the ancients, is perhaps the most irresistible piece of pleasantry that was ever devised by a ludicrous fancy. In his heroes and heroines, Smollett is not happy. For *Random* we have no respect; for *Pickle* we have no esteem; and *Narcissa* and *Emilia* are only the objects of appetite. Since the days of Tom Bowling and the Commodore, we have seen many sailors in print, who display an accurate and profound knowledge of technical *minutiae*; but their humour, if they have any, will not pass muster ashore, the medium through which it is conveyed being to uninstructed ears a mere succession of unintelligible gibberish. And these modern tars have all a striking family likeness to each other, with the exception of some sentimental rope-haulers of the American school, who are evidently monsters of the imagination. But each of Smollett's seamen, though drawn to the life, exhibits the strongest idiosyncrasy of character, and converses in a dialect which can be readily understood by those who have never seen a ship.¹

The next production of Smollett's pen was "An Essay on the External Use of Water, in a letter to Dr. ———; with particular remarks upon the present method of using the Mineral Waters at Bath, in Somersetshire; and a plan for rendering them more safe, agreeable, and efficacious." 1752, 4to. At the period of this publication, Smollett resided at Bath, where he solicited professional employment; but the reputation of the satirist effectually marred the prospects of the physician. Despairing of success in his profession, Dr. Smollett now hired a house at Chelsea, where he entirely devoted himself to literary pursuits. The first fruits of his retirement were, *The Adventures of Ferdinand Count Fathom*, which appeared in 1753. The author's object in this production is, to set up the principal character "as a beacon for the benefit of the inexperienced and unwary." This personage is as much below, as one of Richardson's heroes is above, the standard of general nature. Few men are so virtuous or depraved as to have much sympathy with either; and it may very reasonably be ques-

¹ The incident of Tom Pipes's concealing in his shoe his master's letter to Emilia, it is curious to trace to the following passage in Ovid's *Art of Love*; which has not escaped the laborious research of Hugo, *De prima Scribendi Origine*, p. 154.

Cum possit solea chartas celare ligatas,
Et vincto blandas sub pede ferre notas.

Smollett. tioned, whether any one was ever allured to virtue by viewing the unattainable perfections of Grandison, or deterred from vice by contemplating the superlative villany of Fathom. Besides, a picture of insipid excellence is at least harmless; but there is a moral insanity about some men, which leads them not only to delight in, but sometimes to emulate the achievements of fictitious desperadoes. The most striking passage in this novel, is the adventure in the forest, which creates terror as strong as the convulsions of laughter which reward the exploits of Trunnion and his myrmidons.

But although master of the passions of others, Smollett's own were under very indifferent control. A wretch, called Peter Gordon, whom he had maintained for a series of years, and in support of whose credit he had been prevailed upon to indorse notes, suddenly withdrew into the verge of the court, where, by means of insulting letters and messages, he provoked his benefactor to chastise him in such manner as to furnish grounds for an action of damages. The Hon. Alexander Hume Campbell, who was counsel for the plaintiff, having opened the proceedings with much gratuitous insolence towards the defendant and his witnesses, Smollett addressed a letter to that barrister, couched in very indignant and sarcastic terms, which afterwards found its way into the fifth volume of the *European Magazine*. This infamous prosecution terminated in the discomfiture of Gordon, but the issue of Smollett's dispute with Campbell is involved in obscurity. In the beginning of the year 1755, Smollett published his translation of *Don Quixote*, which was executed amid the anxiety of pecuniary embarrassment, and for which he had been paid by advance. This version is infinitely more spirited and elegant than that of his immediate predecessor Jarvis. But if Smollett has surpassed Motteux in maintaining the solemn fatuity of the knight, he is less happy in rendering the proverbial humour of the squire; for the corresponding phrases in English had already been appropriated, and he was reduced to the necessity of alteration, when there was no room for improvement. After the publication of *Don Quixote*, Smollett paid a visit to his native country. Upon his return to England, he undertook the superintendence of the *Critical Review*. The editorship of that journal involved him in a thousand vexatious disputes with persons who were utterly unworthy of being promoted to the rank of his antagonists. A contemptuous critique on the *Rosciad*, of which he was entirely innocent, provoked the spleen of Churchill, whose brief career was a perpetual crusade against genius and virtue, and whose coarse and rancorous effusions are now consigned to merited oblivion; for posterity has not realized the hopes of an undying name, so confidently expressed by the reverend bard, who proposed to annihilate the reputation of Pope, and who launched his slight javelins at the massy buckler of Johnson.

In 1757, Smollett published a popular compilation, entitled *A Compendium of Authentic and Entertaining Voyages*, 7 vols. 12mo. During the same year was performed and printed *The Reprisal*, a comedy in two acts. The characters in this piece are strongly marked, and the dialogue is extremely spirited, but the situations are conceived with little dramatic artifice; a species of knowledge which often enables the humble retainer of a playhouse to concoct a drama, which shall be admirably well adapted for the stage, and yet prove not more entertaining in the closet than a book of arithmetic. In the same year was published the "Complete History of England, deduced from the Descent of Julius Cæsar to the Treaty of Aix-la-Chapelle, 1748, containing the transactions of one thousand three

hundred and three years." 4 vols. 4to. This surprising effort of industry and genius, is said to have been begun and completed in the course of fourteen months. If not the most accurate and philosophical of historians, Smollett yields to few in the unaffected elegance of his style, and in the graceful animation of his narrative. He had been bred a Whig, and whatever were the motives that led to the political tergiversation which is manifested in this work, it would be uncharitable to suppose that they were those of self-interest; a consideration which does not seem to have influenced any one action of his life.

In 1759, an article appeared in the *Critical Review*, animadverting in strong terms upon the conduct of Admiral Knowles, who had written a pamphlet to vindicate himself from the popular odium which attached to his character, in consequence of his share in a secret expedition to the French coast, which was planned and miscarried in 1757.¹ The admiral having commenced a prosecution against the printer, of which the avowed object was to induce the writer to declare himself, and give him satisfaction of another kind, Smollett, in this dilemma, solicited the good offices of his friend Wilkes, whose rhetoric made no impression on the incensed commander. At this juncture, Smollett stepped boldly forth, and proclaimed himself the author of the obnoxious article, offering the aggrieved party any satisfaction that he might desire. Upon this declaration, the magnanimous flag-officer immediately withdrew his action against the printer, and entered a fresh suit against the reviewer. The result of the action was, that Smollett was fined one hundred pounds, and sentenced to three months imprisonment in the King's Bench.

To cheer the gloom of his confinement, this indefatigable writer employed himself in composing *The Adventures of Sir Launcelot Greaves*, which first appeared in the *British Magazine* for 1760 and 1761, and was published in a separate form in 1762. The eye of criticism has always looked coldly upon this performance. Although it is one of those works, of which the execution must be admitted to surpass the conception, the story of the modern *Don Quixote* is no such incredible figment as it has been pronounced. Sir Launcelot Greaves is represented as a person of diseased understanding; and who shall set bounds to the vagaries of insanity? Nor does Captain Crowe appear to act out of character, in becoming a candidate for the honours of chivalry. For that original is in a state of happy ignorance concerning all terrestrial affairs; and the profession of a knight-errant appears to his unsophisticated understanding to be as lawful a calling as that of a tide-waiter; and it is one which is not at all discordant with the headlong courage and extravagant generosity of a British seaman.

To the modern part of *Universal History*, which was begun in 1759, and completed in 1764, Smollett contributed the histories of France, Italy, and Germany. In 1761 had appeared the first number of his *Continuation of the History of England*, which he finished in 1765; the narrative comprehending the transactions down to that period.

Upon the accession of George III., Smollett appeared in the character of a political partisan, and drew his pen in defence of the administration of Lord Bute, in a weekly paper, entitled *The Briton*. But being speedily tired of protecting from obloquy a minister who was indifferent to public opinion, he retired from the strife, leaving his antagonist, *The North Briton*, master of the field. This contest terminated an intimacy of long standing between Smollett and Wilkes. Notwithstanding his inferiority in talents, that demagogue had some decided advantages over

¹ The offensive words were, "He is an admiral without conduct, an engineer without knowledge, an officer without resolution, and a man without veracity." Knowles was one of the heroes of Carthage, at which memorable expedition he commanded the Weymouth, of 60 guns.

Smollett. his opponent. Wilkes was a cool political pugilist, who gathered courage from the applauses of the mob; while Smollett was greeted with a general burst of popular execration, which worked him into a phrensy that deprived him of his strength.

Smollett's name stands in the title-page of a translation of the works of Voltaire, and also in that of a compilation, entitled *The Present State of all Nations*. These works, to which he contributed sparingly, were published in 1763. In that year he sustained an irreparable loss in the death of his only child, a daughter named Elizabeth, who had attained the fifteenth year of her age. This calamity threw an impenetrable gloom over the brief remainder of his life. In the hope of dissipating his own grief and that of his wife, by change of scene, he passed over into France; in which country, and in Italy, he resided for two years. In 1766, he published his *Travels through France and Italy*. This production displays his usual acuteness of observation, and felicity of expression, but he appears to have contemplated every object through the distorted medium of disease and lacerated feelings. Sterne, who had met the bereaved father abroad, took an opportunity of exulting over the infirmities of rival genius in his *Sentimental Journey*.

In 1766, Smollett visited Scotland for the last time. At this period, he was a martyr to asthma and rheumatic pains, and afflicted with a virulent ulcer on his arm. In the following year, while residing at Bath, he enjoyed a short interval of convalescence, during which he wrote *The Adventures of an Atom*. In this political romance, he has blended, with greater dexterity than judgment, the reckless jollity of Rabelais with the withering sarcasm of Swift. With much wit and humour, this production betrays great physical indelicacy, a latent ferocity of sentiment, and an unqualified abhorrence of the lower order of the community, which is far from edifying. It may here be remarked, that the learning which is scattered through the fictitious narratives of Smollett, would, with proper management, make a most imposing show in works of much graver pretensions. Neither does he ever, like Fielding, hover on the verge of pedantry; nor resort to the disingenuous artifice of dazzling unlettered eyes with borrowed erudition, like Sterne, who had cool effrontery enough to express his sovereign contempt of literary larceny, in the unacknowledged words of Burton.¹

After the publication of this romance, Smollett's complaints returned with increased violence, and his medical friends declared that his only chance of life lay in a more salubrious climate. To the great he never applied in vain, for he never applied at all. His friends however made some fruitless efforts to interest the ministry in his behalf. But from Smollett was sternly withheld that bounty which has often, before and since, been lavished with a prodigal hand upon the most worthless and foolish of mankind. With a constitution worn to the dregs in the service of literature, and with a purse which had been emptied in the lap of indigence, Smollett proceeded to Italy in 1770.

The last, and perhaps the best of all his works, was *The Expedition of Humphrey Clinker*, published in 1771. Each character in the galaxy of originals which are there portrayed, may submit without apprehension to Ben Jonson's test of humour:

When some one peculiar quality
Doth so possess a man, that it doth draw
All his affects, his spirits, and his powers,
In their confluents, all to run one way,
This may be truly said to be a humour.

Having bequeathed this legacy to the public, Smollett died at Monte Nero, a village in the neighbourhood of Leg-

horn, on the 21st of October 1771, in the fifty-first year of his age. A monument was erected to his memory by his widow, and a cenotaph on the banks of the Leven by his cousin, Mr. Smollett of Bonhill.

To a handsome person, and an address at once dignified and engaging, Smollett added colloquial powers of the highest order. His irascible passions were strong, but his social affections were not less so. If it is remembered that his personal and political prejudices were intense, let it not be forgotten that zealous friendship and ardent patriotism were among the number. He was improvident, for his hand was only closed to the necessities of others when he had nothing to bestow. He was a man of undaunted resolution, and lofty independence of mind. He was vindictive, but not implacable, and melted at the first appearance of contrition in those who had injured him. He was jealous of his fame, his sole possession, but he envied that of no other man, whether deserved or otherwise. Of Smollett, as an author, it may be truly said, that of the many different kinds of composition which he has attempted, there is none to which he has not communicated peculiar graces; nor can we hesitate for a moment in adding his name to the scanty list of those who have extended the limits of intellectual enjoyment.²

SMOOTH ISLAND, on the east coast of Van Diemen's Land, in Norfolk Bay, about three-quarters of a mile long.

SMUGGLERS, persons who import or export prohibited goods without paying the duties appointed by the law. When we consider the nature, and still more the history of mankind, we must allow that the enacting of severe penal laws is not the way to prevent crimes. It is indeed much to be wished that there were no such thing as a political crime; for the generality of men, but especially the poorer classes, not discerning the propriety or utility of such laws, consider them as oppressive and tyrannical, and never hesitate to violate them when they can do it with impunity. Instead therefore of punishing smugglers, it would be much better to remove the temptation. But the high duties which have been imposed upon the importation of many different sorts of foreign goods, in order to discourage their consumption in Great Britain, have in many cases served only to encourage smuggling; and in all cases have reduced the revenue of the customs below what more moderate duties would have afforded. The saying of Dr. Swift, that in the arithmetic of the customs two and two, instead of making four, make sometimes only one, holds perfectly true with regard to such heavy duties, which never could have been imposed, had not the mercantile system taught us, in many cases, to employ taxation as an instrument, not of revenue, but of monopoly.

The bounties which are sometimes given upon the exportation of home produce and manufactures, and the drawbacks which are paid upon the re-exportation of the greater part of foreign goods, have given occasion to many frauds, and to a species of smuggling more destructive of the public revenue than any other. In order to obtain the bounty or drawback, the goods, it is well known, are sometimes shipped and sent to sea, but soon afterwards clandestinely re-landed in some other part of the country.

Heavy duties being imposed upon almost all goods imported, our merchant importers smuggle as much, and make entry of as little as they can. Our merchant exporters, on the contrary, make entry of more than they export; sometimes out of vanity, and to pass for great dealers in goods which pay no duty; and sometimes to gain a bounty or a drawback. Our exports, in consequence of these different frauds, appear upon the custom-house books greatly to over-balance our imports; to the unspeakable comfort of those

Smooth
Island,
Smugglers.

¹ See Scott's Biographical Memoirs of eminent Novelists, vol. i. p. 294.

² For more circumstantial details of the life of Smollett, the reader is referred to the narratives of Dr. Anderson and Dr. Moore.

Smyrna. politicians who measure the national prosperity by what they call the balance of trade.

SMYRNA, a large commercial city of Asia Minor, situated at the head of a long and winding gulph on the western coast of the Grecian Archipelago, and, with the exception of Constantinople, the most important sea-port of the Turkish empire. It has an imposing appearance from the sea; and its bay, besides numerous small craft, is frequented by ships from the chief ports of Europe. The present town is about four miles in circuit, and extends about a mile along the water. The bay is so completely landlocked, that nothing is seen from the town but the projecting points that enclose it. The interior of the city is not so inviting as its aspect from without. The streets are narrow, dirty, and ill-paved, and the houses are for the most part unseemly wooden edifices; but though their external appearance is rather gloomy, the situation of those built along the water is delightful, as they have all gardens attached to them, at the foot of which are summer-houses overlooking the sea. Of late years Smyrna has been greatly improved, and well-built hotels and excellent lodging-houses now invite the traveller to a city where, we are assured, not only the "decencies of house-keeping and house-furnishing, but the comforts and luxuries of life flow in abundantly from London and from Paris." The houses of painted wood, which were so unworthy of its ancient fame, are rapidly giving way to palaces of stone, which are rising in all directions; and in the course of a few years Smyrna will really be an elegant city, with every indication of prosperity and opulence. The bazaars, though well provided with goods, are by no means splendid in their structure. There are two very fine caravanseras, enclosing square courts, which, being covered with cupolas, make a handsome appearance. The shops are also arched over, and are very fine. The principal buildings are the mosques, the baths, the inns, and the market-place. Some of the mosques are very noble edifices; and likewise the inns, as already remarked. At the east end of the city is a large hill, about three quarters of a mile in circumference, on which the castle was built. The edifice appears to have been the work of the Genoese, and to have been by no means magnificent. Along its circumference, however, may still be traced the remains of a very thick and strong wall, apparently that of the ancient castle, and corresponding in its appearance with another which appears to have surrounded the whole city. Behind the city is an extensive plain, most luxuriant and highly cultivated, and crowned with numerous olive-trees; it is watered by a small river, from fifty to a hundred yards broad, which contains little water, unless when artificially confined. Of the former magnificence of this ancient city, scarcely any traces are now to be seen. The reason of this is stated by Pococke to be, that the ancient structures have been demolished to furnish materials for modern ones; and a more recent traveller, Arundel, assigns much the same reason. The present does not occupy the site of the ancient city. The latter was situated on the hills, to the south of the present town; but the earthquakes to which it is subject, and by which it was more than once nearly destroyed, together with the greater convenience of trade, occasioned its removal to the plain below, and to the lower declivities of the mountains; and accordingly it is observed by Mr. Arundel, that "few of the Ionian cities have furnished more relics of antiquity, or of greater merit, than Smyrna. But the convenience of transporting them, with the number of investigations, have exhausted the ruins; it is therefore not at all wonderful, that of the stoas and temples, the very ruins have vanished; and it is now extremely difficult to determine the sites of any of the ancient buildings, with the exception of the stadium, the theatre, and the temple of Jupiter Acraeus, which was within the Acropolis." Of the stadium here mentioned,

Smyrna. the ground-plan only remains, stripped of its marble seats and decorations; and only the foundations can be seen of the splendid theatre, built on the slope of a hill, the site of which is now covered with houses. On a gateway belonging to the castle is a colossal statue of very fine workmanship, though much mutilated, which has been supposed to be that of the Amazon Smyrna, from which the city is reported to have derived its name. Marks of a very extensive aqueduct may also be traced, though a late traveller doubts of its very high antiquity.

Smyrna is increasing in population and in wealth. It is a great commercial emporium, and a crowded resort of merchants from all countries, with their various costumes, language, and religion. It is the most general entrepôt for the productions of the Levant, and its port is crowded with ships from the most distant ports. It has a safe and capacious roadstead, where there is good anchorage, and where the largest ships can load and unload close to the wharfs. Nearly every power in Europe has a consul at Smyrna, who is vested with more than ordinary authority. There are about twenty commercial houses at Smyrna; and the Venetians, Genoese, and other Italians, the Dalmatians, Dutch, French, and Americans, have also establishments. No other town in Asiatic or European Turkey has so great a trade. All classes are engaged in business. The higher order of Franks deal often to a great extent; while the lower classes, consisting of persons from nearly every country in the Mediterranean, obtain employment as boatmen, carpenters, tailors, shoemakers, and the trade is carried on by Jews, mostly brokers. The Greek dealers are in general petty shopkeepers, very cunning, and not remarkably trustworthy. The Jews are liable to the same objections, but they often guarantee each other's transactions. The Armenians are the largest traffickers, but though usually strict at a bargain, they are generally solvent, and honourable as well as honest. The Turkish dealers, are, however, superior to them in all moral qualities, as they are inferior in means and in talents for business; yet they sometimes deal largely, and their bond is punctually discharged the day it becomes due.

The largest article of import is coffee, the favourite beverage of all classes in Turkey and Western Asia. The chief supply is derived from America, from England, France, also in smaller quantities from Holland, Trieste, Leghorn, and Genoa. Sugar is the next article in importance, and the supply is furnished by the same countries which supply coffee. Indigo is exclusively imported from England. The exports from Smyrna consist of silk from Brassa, about two hundred miles from Smyrna, which is forwarded by caravans to this port, and is the richest article of export. This branch of trade promises to increase, as there is so great a demand for the raw material in Britain. Opium is largely exported, particularly to America, whence it has found its way to China, though the trade is now vigorously proscribed by the Chinese authorities, and has caused the expulsion of the English from the port of Canton. Drugs and gums are exported to the English market; galls for England, Germany, France, and Valona or Avlona, a sea-port in European Turkey at the entrance of the Gulf of Venice. British shipping receives full cargoes of this more than of any other article, with the exception of fruit. These, with madder, sponges, olive-oil, wax, hare-skins, goats and sheep's wool, complete the articles of export. Figs and raisins may be considered as the great staple article of Smyrna, which are celebrated for their excellence, and are exported in large quantities. The exports from this country to Smyrna are increasing. From 1827 to 1830, they had increased from L.531,704 to L.1,139,616, nine-tenths of which were cotton goods, for which there is a great desire, being cheaper than those from any other quarter; and the late commercial treaty concluded with Turkey in 1838 will extend this trade.

Snaffle.
||
Sneezing.

Smyrna is well supplied with provisions, with fish and fruit of all kinds, and with excellent wines from the interior or from the islands. Of late years a great change has taken place in the manners and character of its inhabitants. Mr. Arundel, who resided many years in the place as British chaplain, has stated that numerous printing-presses, and journals in the different languages, viz. French, English, Greek, and Italian, have familiarised the inhabitants of Smyrna with the politics and literature of Europe. Even a few years ago, the Greek youths of Smyrna had no other means of acquiring knowledge, but very inferior day-schools and private instruction. There are now not only several seminaries, one dignified with the name of a college, for the education of the French youth of both sexes, but likewise for the Greeks there are various free schools, where numerous pupils not only learn the rudiments of knowledge, but also every branch of polite literature. There is a public dispensary, where persons of all nations are gratuitously relieved without regard to any distinction of religion. It is not easy to form an accurate account of the population. Mr. Arundel estimates the number of inhabitants from 100,000 to 120,000. There are twenty mosques, three Greek churches, two for Roman Catholics, one Armenian, one Protestant Episcopal, and one Dutch. The Jews have numerous synagogues, and the environs are adorned with cypress groves, the burial-places of the Mahometans.

Smyrna was one of the most celebrated cities in the ancient world, and claims, along with others, to be the birth-place of Homer. It is said originally to have been a colony from Ephesus, and soon attained to great prosperity. The original city was destroyed by the Lydians, and was rebuilt by Antigonus and Lysimachus, though on a somewhat different spot. It surpassed its former splendour: the streets were beautifully laid out, well paved, and adorned with porticoes. Under the Roman emperors, Smyrna, which was esteemed one of the most beautiful of the Ionian cities, was ruined by the desolations of the barbarians. It was captured by Tamerlane, and sacked, with great slaughter of the inhabitants. When the Turks gained undisputed possession of the Greek empire, and peace was restored, commerce again revived, owing to the favourable position of the place; and from that period it enjoyed almost uninterrupted repose, until the era of the Greek revolution. That event has now passed away, and Smyrna is prospering as the greatest commercial city in the Levant. Long. 27. 4. 45. E. Lat. 38. 29. N.

SNAFFLE, in the manege, is a very slender bit-mouth without any branches. It is much used in England, the true bridles being reserved for war.

SNAITH, a town in the Wapentake of Osgoldcross, in the West Riding of the county of York, one hundred and seventy-four miles from London. It stands on the navigable river Aire, in a pleasant situation. The inhabitants were in 1801, 688; in 1811, 743; in 1821, 834; and in 1831, 885; but the inhabitants of the whole parish are 8530.

SNAKE, in *Zoology*. See SERPENTS.

SNARES, a cluster of seven craggy islands in the South Pacific Ocean, discovered by Vancouver. Long. 166. 20. E. Lat. 48. 3. S.

SNEEK, a town in the Netherlands, in the province of Friesland, the capital of a circle of the same name. It is situated on a canal connected with Leuwarden, a place of much activity, having many saw and oil mills, and some manufactories of pottery ware, and exporting much corn. It contains two churches, a stadthouse, and 6455 inhabitants.

SNEEZING, a convulsive motion of the muscles of the

breast, by which the air is expelled from the nose with much vehemence and noise. It is caused by the irritation of the upper membrane of the nose, excited by acrid substances floating in the air, or by medicines called *sternutatory*.

This irritation is occasioned either externally, by strong smells, or by dust floating in the air, and taken in by inspiration; or by sharp pungent medicines, as cresses and other sternutatories, which vellicate the membrane of the nose; or internally, by the acrimony of the lymph or mucus, which naturally moistens that membrane. The matter cast forth in sneezing comes primarily from the nose and throat, the pituitary membrane continually exuding a mucus; and, secondarily, from the breast, the trachea, and the bronchia of the lungs.

The practice of saluting the person who sneezed existed in Africa, among nations unknown to the Greeks and Romans. The accounts we have of Monomotapa inform us,¹ that when the prince sneezes, all his subjects in the capital are advertised of it, that they may offer up prayers for his safety. The author of the *Conquest of Peru* assures us, that the cacique of Guachoia having sneezed in presence of the Spaniards, the Indians of his train fell prostrate before him, stretched forth their hands, and displayed to him the accustomed marks of respect, while they invoked the sun to enlighten him, to defend him, and to be his constant guard.

Every body knows that the Romans saluted each other on these occasions: and Pliny relates,² that Tiberius exacted these signs of homage when drawn in his chariot. Superstition, whose influence can debase every thing, had degraded this custom for several ages, by attaching favourable or unfavourable omens to sneezing, according to the hour of the day or night, according to the signs of the zodiac, according as a work was more or less advanced, or according as one had sneezed to the right or to the left.³ If a man sneezed at rising from table or from his bed, it was necessary for him to sit or lie down again. You are struck with astonishment, said Timotheus to the Athenians, who wished to return into the harbour with their fleet,⁴ because he had sneezed; you are struck with astonishment, because among ten thousand there is one man whose brain is moist.

Polydore Virgil pretends, that in the time of Gregory the Great, there reigned in Italy an epidemic distemper, which carried off by sneezing all those who were seized by it; and that this pontiff ordered prayers to be made against it, accompanied by certain signs of the cross. But besides that there are very few cases in which sneezing can be considered as dangerous, and that it is frequently a favourable symptom,⁵ it is evident, that we ought not to date from the sixth century the origin of a custom which loses itself in the obscurity of antiquity. Avicenna and Cardan aver that it is a sort of convulsion, which gives occasion to dread an epilepsy, and that this disease is endeavoured to be warded off by prayers. Clement of Alexandria considers it as a mark of intemperance and effeminacy, which ought to be proscribed; and he inveighs bitterly against those who endeavour to procure sneezing by external aid. Montaigne, on the contrary, explains this fact in a tone rather cynical. It is singular enough, that so many ridiculous, contradictory, and superstitious opinions, have not abolished those customary civilities which are still preserved equally among high and low; and which only the Anabaptists and Quakers have rejected, because they have renounced salutations in every case.

Among the Greeks sneezing was almost always a good omen. It excited marks of tenderness, of respect, and at-

¹ Strada, Prol. Acad.

⁴ Frontin. lib. i. cap. 11.

² Plin. Hist. Nat. lib. ii. cap. 2.

⁵ Hippocrates. Halleri Phys.

³ Spond. Comment. in Homerum.

Sniggling.
||
Snow.

tachment. The genius of Socrates informed him by sneezing, when it was necessary to perform any action. The young Parthenis, hurried on by her passion, resolved to write to Sarpedon an avowal of her love; she sneezes in the most tender and impassioned part of her letter: this is sufficient for her; this incident supplies the place of an answer, and persuades her that Sarpedon is her lover. Penelope, harassed by the vexatious courtship of her suitors, begins to curse them all, and to pour forth vows for the return of Ulysses. Her son Telemachus interrupts her by a loud sneeze. She instantly exults with joy, and regards this sign as an assurance of the approaching return of her husband. Xenophon was haranguing his troops; a soldier sneezed in the moment when he was exhorting them to embrace a dangerous but necessary resolution. The whole army, moved by this presage, determined to pursue the project of their general; and Xenophon ordered sacrifices to Jupiter the preserver.

This religious reverence for sneezing, so ancient, and so universal even in the times of Homer, always excited the curiosity of the Greek philosophers, and of the rabbins. These last have spread a tradition, that, after the creation of the world, God made a general law to this purport, that every living man should sneeze but once in his life, and that at the same instant he should render up his soul into the hand of his Creator, without any preceding indisposition. Jacob obtained an exemption from the common law, and the favour of being informed of his last hour. He sneezed and did not die; and this sign of death was changed into a sign of life. Notice of this was sent to all the princes of the earth; and they ordained that in future sneezing should be accompanied with forms of blessing, and vows for the persons who sneezed.

Aristotle likewise remounts to the sources of natural religion. He observes, that the brain is the origin of the nerves, of our sentiments, our sensations, the seat of the soul, the image of the Divinity; that upon all these accounts, the substance of the brain has ever been held in honour; that the first men swore by their head; that they durst not touch nor eat the brains of any animal; that it was even a sacred word which they dared not to pronounce. Filled with these ideas, it is not wonderful that they extended their reverence even to sneezing. Such is the opinion of the most ancient and sagacious philosophers of Greece.

According to mythology, the first sign of life Prometheus's artificial man gave was by sternutation. This supposed creator is said to have stolen a portion of the solar rays; and filling with them a phial, which he had made on purpose, sealed it up hermetically. He instantly flies back to his favourite automaton, and opening the phial, holds it close to the statue; the rays still retaining all their activity, insinuate themselves through the pores, and set the fictitious man a-sneezing. Prometheus, transported with the success of his machine, offers up a fervent prayer, with wishes for the preservation of so singular a being. His automaton observed him, and, remembering his ejaculations, was very careful, on the like occasions, to offer these wishes in behalf of his descendants, who perpetuated it from father to son in all their colonies.

SNIGGLING, a method of fishing for eels, chiefly used in the day time, when they are found to hide themselves near weirs, mills, or flood-gates.

SNIFE. See **ORNITHOLOGY**.

SNOW, a well-known meteor, formed by the freezing of the vapour of water in the atmosphere. It differs from hail and hoar-frost, in being as it were crystallized, which they are not. This appears in examining a flake of snow by a magnifying glass; when the whole of it will appear to be composed of fine shining spicula diverging like rays from a centre. As the flakes fall down through the atmosphere, they are continually joined by more of those radiated spi-

cula, and thus increase in bulk like the drops of rain or hailstones. Dr. Grew, in a discourse of the nature of snow, observes, that many parts thereof are of a regular figure, for the most part stars of six points, and are as perfect and transparent ice as any we see on a pond. Upon each of these points are other collateral points, set at the same angles as the main points themselves; among which there are divers other irregular, which are chiefly broken points, and fragments of the regular ones. Others also, by various winds, seem to have been thawed and frozen again into irregular clusters, so that it seems as if the whole body of snow were an infinite mass of icicles irregularly figured; that is, a cloud of vapours being gathered into drops, the said drops forthwith descend; upon which descent, meeting with a freezing air as they pass through a colder region, each drop is immediately frozen into an icicle, shooting itself forth into several points; but these still continuing their descent, and meeting with some intermitting gales of warmer air, or in their continual waftage to and fro, touching upon each other, some of them are a little thawed, blunted, and again frozen into clusters, or entangled so as to fall down in what we call flakes.

The lightness of snow, although it is firm ice, is owing to the excess of its surface, in comparison to the matter contained under it; as gold itself may be extended in surface till it ride upon the least breath of air.

The whiteness of snow is owing to the small particles into which it is divided; for ice, when pounded, will become equally white. An artificial snow has been made by the following experiment. A tall phial of aquafortis being placed by the fire till it is warm, and filings of pure silver, a few at a time, being put into it, after a brisk ebullition, the silver will dissolve slowly. The phial being then placed in a cold window, as it cools, the silver particles will shoot into crystals, several of which running together, will form a flake of snow, which will descend to the bottom of the phial. While they are descending, they represent perfectly a shower of silver snow, and the flakes will lie upon one another at the bottom, like real snow upon the ground.

According to Signor Beccaria, clouds of snow differ in nothing from clouds of rain, but in the circumstance of cold that freezes them. Both the regular diffusion of the snow, and the regularity of the structure of its parts, particularly some figures of snow or hail which fall about Turin, show that clouds of snow are acted upon by some uniform cause like electricity; and he endeavours to show how electricity is capable of forming these figures. He was confirmed in his conjectures by perceiving, that his apparatus for observing the electricity of the atmosphere never failed to be electrified by snow as well as rain. Professor Winthrop sometimes found his apparatus electrified by snow when driven about by the wind, though it had not been affected by it when the snow itself was falling. A more intense electricity, according to Beccaria, unites the particles of hail more closely than the more moderate electricity does those of snow, in the same manner as we see that the drops of rain which fall from thunder-clouds are larger than those which fall from others, though the former descend through a less space.

But we are not to consider snow merely as a curious and beautiful phenomenon. The Great Dispenser of universal bounty has so ordered it, that it is eminently subservient, as well as all the works of creation, to his benevolent designs. Were we to judge from appearances only, we might imagine, that so far from being useful to the earth, the cold humidity of snow would be detrimental to vegetation. But the experience of all ages asserts the contrary. Snow, particularly in those northern regions where the ground is covered with it for several months, fructifies the earth, by guarding the corn or other vegetables from the intenser cold of the air, and especially from the cold piercing winds.

Snow.

Snowdon
||
Soap.

Snow or ice water is always deprived of its fixed air, which escapes during the process of congelation. Accordingly, as some of the inhabitants of the Alps who use it for their constant drink, have enormous wens upon their throats, it has been ascribed to this circumstance. If this were the cause of these wens, it would be easy to remove it by exposing the snow-water to the air for some time. But several eminent physicians have rejected the notion that snow-water is the cause of these wens; for in Greenland, where snow-water is commonly used, the inhabitants are not affected with such swellings; and on the other hand, they are common in Sumatra, where snow is never seen.

SNOWDON, one of the highest mountains in Wales. It is within the county of Carnarvon, but extends to the borders of Merionethshire. The highest point of the range is 3571 feet above the level of the sea. The snow begins to fall on it in November, and is seldom melted till the middle of June. It is easily accessible in several directions. The view from the summit is extensive and grand, on a clear day, which does not often occur. The hills of Scotland are to be seen, with a part of the coast, as well as the Isle of Man; and the hills of Lancashire, Westmoreland, and Cumberland, and, in some very translucent days, the hills of Kerry, in Ireland, have been perceived. The mountain of Snowdon was held sacred by the ancient Britons.

SNYDERS, FRANCIS, a Flemish painter, born at Antwerp in 1579, and bred under his countryman Henry Van Balen. His genius first displayed itself in painting fruit; he afterwards attempted animals, huntings, &c., in which he exceeded all his predecessors. He also painted kitchens, &c., and gave dignity to subjects that seemed incapable of it. He was made painter to Ferdinand and Isabella, archduke and duchess, and became attached to the house of the cardinal infant of Spain. The king of Spain and the elector Palatine adorned their palaces with huntings by this artist. Rubens, Jordaens, and Snyders, used to co-operate in the enriching of each other's pictures according to their several talents; and thus they became more valuable than if finished by either of them singly. Snyders died in 1657.

SOAGHIM, a town of Hindustan, in the Mahratta territories, province of Malwah, sixty miles west from Ooojain. Long. 74.50. E. Lat. 23. 12. N.

SOANE RIVER has its rise on the east of the table land of Omercuntire, in the province of Gundwana. It flows through Pindarah, where, being joined by numerous other streams from the north-east side of this mountainous territory, it proceeds in a northerly course to the Ganges, which it joins in the province of Bahar, after a winding course of about five hundred miles.

SOANK, a small river of Hindustan, in the province of Bahar, whence it flows in a southerly direction, and being joined by the small river Borkee, their united streams form the Braminy Nuddy river.

SOAP, a composition of caustic, fixed alkaline salt, and oil, sometimes hard and dry, sometimes soft and liquid; much used in washing, whitening linens, and by dyers and fullers. Soap may be made by several methods, which however all depend upon the same principle. The soap which is used in medicine is made without heat.

In manufactures where large quantities of it are prepared, soap is made with heat. A lixivium of quicklime and soda is made, but is less concentrated than that above referred to, and only so much that it can sustain a fresh egg. A part of this lixivium is to be even diluted and mixed with an equal weight of oil of olives. The mixture is to be put on a gentle fire, and agitated, that the union may be accelerated. When this mixture begins to unite well, the rest of the lixivium is to be added to it; and the whole is to be digested with a very gentle heat, till the soap be completely made. A trial is to be made of it, to examine whether the just proportion of oil and alkali has been observed. Good soap of this kind ought to be firm, and very white

when cold; not subject to become moist by exposure to air, and entirely miscible with pure water, to which it communicates a milky appearance, but without any drops of oil floating on the surface. When the soap has not these qualities, the combination has not been well managed, or the quantity of salt or oil is too great, which faults must be corrected.

In soft or liquid soaps, green or black soaps, cheaper oils are employed, as oil of nuts, of hemp, of fish, &c. These soaps, excepting in consistence, are not essentially different from white soap. Fixed alkalies are much disposed to unite with oils that are not volatile, both vegetable and animal, since this union can be made even without heat. The compound resulting from this union partakes at the same time of the properties of oil and of alkali; but these properties are modified and tempered by each other, according to the general rule of combinations. Alkali formed into soap has not nearly the same acrimony as when it is pure; it is even deprived of almost all its causticity, and its other saline alkaline properties are almost entirely abolished. The same oil contained in soap is less combustible than when pure, from its union with the alkali, which is an inflammable body. It is miscible, or even soluble, in water, to a certain degree, by means of the alkali. Soap is entirely soluble in spirit of wine; and still better in aquavita sharpened by a little alkaline salt, according to an observation of Mr. Geoffroy.

The manufacture of soap in London first began in the year 1524; before which time this city was served with white soap from foreign countries, and with gray soap speckled with white from Bristol, which was sold for a penny a pound; and also with black soap, which sold for a halfpenny a pound.

Concerning the decomposition of soap by means of acids, we must observe, first, that all acids, even the weakest vegetable acids, may occasion this decomposition, because every one of them has a greater affinity than oil with fixed alkali. Secondly, these acids, even when united with any basis, excepting fixed alkali, are capable of occasioning the same decomposition; whence all ammoniacal salts, all salts with bases of earth, and all those with metallic bases, are capable of decomposing soap, in the same manner as disengaged acids are; with this difference, that the oil separated from the fixed alkali, by the acid of these salts, may unite more or less intimately with the substance which was the basis of the neutral salt employed for the decomposition.

Soap may also be decomposed by distillation, as Lemery has shown. When first exposed to fire, it yields a phlegm called by him a *spirit*; which nevertheless is neither acid nor alkaline, but some water which enters into the composition of soap. It becomes more and more coloured and empyreumatic as the fire is increased, which shows that it contains the most subtle part of the oil. It seems even to raise along with it, by help of the oil and action of the fire, a small part of the alkali of the soap: for, as the same chemist observes, it occasions a precipitate in a solution of corrosive sublimate. After this phlegm the oil rises altered, precisely as if it had been distilled from quicklime, that is, empyreumatic, soluble in spirit of wine, at first sufficiently subtle and afterwards thicker. An alkaline residuous coal remains in the retort, consisting chiefly of the mineral alkali contained in the soap, and which may be disengaged from the coal by calcination in an open fire, and obtained in its pure state.

Alkaline soaps are very useful in many arts and trades, and also in chemistry and medicine. Their principal utility consists in a deterative quality that they receive from their alkali, which, although it is in some measure saturated with oil, is yet capable of acting upon oily matters, and of rendering them saponaceous and miscible with water. Hence soap is very useful to cleanse any substances from all fat matters with which they happen to be soiled. Soap is therefore daily used for the washing and whitening of linen, for

Soap.

Socage.
||
Society.

the cleansing of woollen cloths from oil, and for whitening silk and freeing it from the resinous varnish with which it is naturally covered. Pure alkaline lixiviums being capable of dissolving oils more effectually than soap, might be employed for the same purposes; but when this activity is not mitigated by oil, as it is in soap, they are capable of altering, and even of destroying entirely, by their causticity, most substances, especially animal matters, as silk, wool, and

others; whereas soap cleanses from oil almost as effectually as pure alkali, without danger of altering or destroying; a circumstance which renders it very useful.

Soap was imperfectly known to the ancients. It is mentioned by Pliny as made of fat and ashes, and as an invention of the Gauls. Aretæus and others inform us, that the Greeks obtained their knowledge of its medical use from the Romans.

The following Table shows the quantity of Soap charged with the duties of Excise in the United Kingdom during the years 1835, 1836, and 1837, and the number of Soap-makers during the same period, with the duties paid by them.

	Quantities Charged.			Amount of Duty.		
	1835.	1836.	1837.	1835.	1836.	1837.
Hard Soap, lbs.	148,806,207	146,539,210	140,822,611	£930,038 15 8	£915,860 18 4½	£880,141 6 3
Soft Soap.....	12,103,109	13,358,894	11,794,834	50,429 12 5	55,662 1 2	49,145 2 10
Soap-makers....	450	432	402	1,800 0 0	1,728 0 0	1,608 0 0

The direct duty charged on hard soap is 1½d. per lb., and on soft soap 1d. per lb. Previously to June 1833, the duty on hard soap was 3d. per lb. The exorbitant amount of the tax, which was fully 100 per cent. on the cost, gave occasion to a great deal of smuggling, which is still carried on to some extent, and is facilitated by the injudicious regulation of taxing this commodity in one part of the kingdom, and leaving it untaxed in another; no duty being charged on soap manufactured in Ireland, and the duty being drawn back from such quantities as are imported into Ireland from Britain.

SOCAGE, in its most general and extensive signification, seems to denote a tenure by any certain and determinate service. And in this sense it is by our ancient writers constantly put in opposition to chivalry or knight-service, where the tenure was precarious and uncertain. The service must therefore be certain, in order to denominate it socage; as to hold by fealty and twenty shillings rent; or, by homage, fealty, and twenty shillings rent; or, by homage and fealty without rent; or, by fealty and certain corporal service, as ploughing the lord's land for three days; or, by fealty only without any other service; for all these are tenures in socage.

Socage is of two sorts: *free-socage*, where the services are not only certain but honourable; and *villein-socage*, where the services, though certain, are of a baser nature. Such as hold by the former tenure are called, in Glanville and other subsequent authors, by the name of *liberi socemanni*, or tenants in free-socage. The word is derived from the Saxon appellation *soc*, which signifies liberty or privilege, and, being joined to an usual termination, it forms *socage*, in Latin *socagium*, signifying a free or privileged tenure.

It seems probable that the socage-tenures were the relics of Saxon liberty; retained by such persons as had neither forfeited them to the king, nor been obliged to exchange their tenure for the more honourable, as it was called, but at the same time more burthensome, tenure of knight-service. This is peculiarly remarkable in the tenure which prevails in Kent, called *gavelkind*, which is generally acknowledged to be a species of socage-tenure; and its preservation from the innovations of the Norman conqueror is a fact universally known. And those who thus preserved their liberties were said to hold in free and common socage.

Definition. SOCIETY, a number of rational and moral beings, united for their common preservation and happiness. There are shoals of fishes, herds of quadrupeds, and flocks of birds.

VOL. XX.

We call crows and beavers, and several other species of animals, *gregarious*; but it is hardly good English to say that they are *social*. It is only human society that can be regarded in this light, and the phenomena which it presents are highly worthy of our notice.

Such are the advantages which each individual evidently derives from living in a social state; and so helpless does any human being appear in a solitary state, that we are naturally led to conclude, that if there ever was a period at which mankind were solitary beings, that period could not be of long duration; for their aversion to solitude and love of society would soon induce them to enter into social union. Such is the opinion which we are led to conceive when we compare our own condition as members of civilised and enlightened society with that of the brutes around us, or with that of savages in the earlier and ruder periods of social life. When we hear of Indians wandering naked through the woods, destitute of arts, unskilled in agriculture, scarcely capable of moral distinctions, void of all religious sentiments, or possessed with the most absurd notions concerning superior powers, and procuring means of subsistence in a manner equally precarious with that of the beasts of prey, we look down with pity on their condition, or turn from it with horror. When we view the order of cultivated society, and consider our institutions, arts, and manners, we rejoice over our superior wisdom and happiness. Man in a civilized state appears a being of a superior order to man in a savage state; yet some philosophers tell us, that it is only he who, having been educated in society, has been taught to depend upon others, that can be helpless or miserable when placed in a solitary state. They view the savage who exerts himself with intrepidity to supply his wants, or bears them with fortitude, as the greatest hero, and possessing the greatest happiness.

Whatever be the supposed advantages of a solitary state, certain it is that mankind, at the earliest periods, were united in society. Various theories have been formed concerning the circumstances and principles which gave rise to this union; but it has been sufficiently proved, that the greater part of them are founded in error; that they suppose the original state of man to have been that of savages; and that such a supposition is contradicted by the most authentic records of antiquity. For though the records of the earlier ages are generally obscure, fabulous, and imperfect, yet happily there is one free from the imperfections of the rest, and of undoubted authenticity, to which we may safely have recourse. This record is the Pentateuch of Moses, which presents us with a genuine account of the origin of man and of society.

Societies.

SOCIETIES, associations voluntarily formed by a number of individuals for promoting knowledge, industry, or virtue. They may therefore be divided into three classes; societies for promoting science and literature, societies for encouraging and promoting arts and manufactures, and societies for diffusing religion and morality and relieving distress. These, however, are so numerous and fluctuating, that it would be difficult to offer any thing like an accurate account of them. The reader is referred for information on the subject to the articles, LONDON, DUBLIN, EDINBURGH, and the other towns and countries where these institutions have been established. We shall only notice the Royal Societies of London and Edinburgh.

The Royal Society of London is an academy or body of persons of eminent learning, instituted by Charles II., for the promoting of all the different branches of physical knowledge. The origin of this society is traced by Dr. Sprat, its earliest historian, no farther back than to "some space after the end of the civil wars" in the seventeenth century. The scene of the first meetings of the learned men who laid the foundation of it, is by him fixed in the university of Oxford, at the lodgings of Dr. Wilkins, warden of Wadham College. But Dr. Birch, on the authority of Dr. Wallis, one of its earliest and most considerable members, assigns it an earlier origin. According to him, certain worthy persons, residing in London about the year 1645, being "inquisitive into natural and the new and experimental philosophy, agreed to meet weekly on a certain day, to discourse upon such subjects, and were known by the title of *The Invisible or Philosophical College*." In the years 1648 and 1649, the company who formed these meetings was divided, part retiring to Oxford and part remaining in London; but they continued the same pursuits as when united, corresponding with each other, and giving a mutual account of their respective discoveries. About the year 1659 the greater part of the Oxford society returned to London, and again uniting with their fellow-labourers, met once, if not twice a-week at Gresham College, during term-time, till they were scattered by the public distractions of that year, and the place of their meeting made quarters for soldiers. On the restoration in 1660 their meetings were revived, and attended by a greater concourse of men eminent for their rank and learning. They were at last taken notice of by the king, who having himself a considerable taste for physical science, was pleased to grant them an ample charter, dated the 15th of July 1662, and afterwards a second dated 15th April 1663, by which they were erected into a corporation, consisting of a president, council, and fellows, for promoting natural knowledge; and to give their investigations, against which strange prejudices were entertained, every possible support, he sometimes honoured their meetings with his presence.

Their manner of electing fellows is by balloting. Their council consists of twenty-one, including the president, vice-president, treasurer, and two secretaries, eleven of which are continued for the next year, and ten more added to them; all being chosen on St. Andrew's day.

The services which this illustrious society has rendered to the public are very great. They have improved naval, civil, and military architecture; advanced the security and perfection of navigation; improved agriculture; and put not only this kingdom, but also Ireland, the plantations, &c., upon planting. They have registered experiments, histories, relations, observations, &c., and reduced them into one common stock; and have, from time to time, published those which they reckoned most useful, under the title of *Philosophical Transactions*, &c. They have a library adapted to their institution; towards which Mr. Henry Howard, afterwards duke of Norfolk, contributed the Norfolkian library, and which has been vastly increased by a continual series of benefactions.

The Royal Society of Edinburgh was incorporated by

royal charter on the 29th of March 1783, and has for its object the cultivation of every branch of science, erudition, and taste. Its rise and progress towards its present state was as follows. In the year 1718 a literary society was established in Edinburgh by the learned Ruddiman and others, which in 1731 was succeeded by a society instituted for the improvement of medical knowledge. In the year 1739 the celebrated Maclaurin conceived the idea of enlarging the plan of this society, by extending it to subjects of philosophy and literature. The institution was accordingly new-modelled by a printed set of laws and regulations, the number of members was increased, and they were distinguished from that time by the title of *The Society for Improving Arts and Sciences*, or more generally by the title of *The Philosophical Society of Edinburgh*. Its meetings, however, were soon interrupted by the disorders of the country during the rebellion in 1745; and they were not renewed till the year 1752. Soon after this period the first volume of the *Transactions of the Philosophical Society of Edinburgh* was published, under the title of *Essays and Observations, Physical and Literary*, and was followed by other volumes of acknowledged merit. About the end of the year 1782, in a meeting of the professors of the university of Edinburgh, many of whom were likewise members of the Philosophical Society, and warmly attached to its interests, a scheme was proposed by the late Dr. Robertson, principal of the university, for the establishment of a new society on a more extended plan, and after the model of some of the foreign academies. It appeared an expedient measure to solicit the royal patronage to an institution of this nature, which promised to be of national importance, and to request an establishment by charter from the crown. The plan was approved and adopted; and the Philosophical Society, joining its influence as a body in seconding the application from the university, his majesty, as we have already observed, was graciously pleased to incorporate The Royal Society of Edinburgh by charter.

Members are elected by ballot. The general business of the society is managed by a president, two vice-presidents, with a council of twelve, a general secretary, and a treasurer. These officers are chosen by ballot annually on the last Monday of November. All public deeds, whether of a civil or of a literary nature, are transacted by this board, and proceed in the name of the president or vice-president.

As it was thought that the members would have a greater inducement to punctual attendance on the meetings of the society, if they had some general intimation of the nature of the subjects which were to be considered, and made the topics of conversation, it was therefore resolved to divide the society into two classes, which should meet and deliberate separately. One of these classes is denominated the *Physical Class*, and has for its department the sciences of mathematics, natural philosophy, chemistry, medicine, natural history, and whatever relates to the improvement of arts and manufactures. The other is denominated the *Literary Class*, and has for its department literature, philology, history, antiquities, and speculative philosophy. There are many valuable papers in the volumes that have been published of the *Transactions* of this society.

SOCIETY Isles, a cluster of isles, so named by Captain Cook in 1769. They are situated between the latitudes of 16. 10. and 16. 55. south, and between the longitudes of 150. 57. and 152. west. See POLYNESIA.

SOCINIANS, in church history, a sect of Christian heretics, so called from their founder Faustus Socinus. They maintain, "that Jesus Christ was a mere man, who had no existence before he was conceived by the Virgin Mary; that the Holy Ghost is no distinct person, but that the Father is truly and properly God. They own, that the name of God is given in the Holy Scriptures to Jesus Christ; but contend, that it is only a deputed title, which however in-

Society
Socinians.

Socinus. vests him with an absolute authority over all created beings, and renders him an object of worship to men and angels. They deny the doctrines of satisfaction and imputed righteousness; and say that Christ only preached the truth to mankind, set before them in himself an example of heroic virtue, and sealed his doctrines with his blood. Original sin and absolute predestination they esteem scholastic chimeras. They likewise maintain the sleep of the soul, which they say becomes insensible at death, and is raised again with the body at the resurrection, when the good shall be established in the possession of eternal felicity, while the wicked shall be consigned to a fire that will not torment them eternally, but for a certain duration in proportion to their demerits."

This sect has long been indignant at being styled *Socinians*. They disclaim every human leader; and professing to be guided solely by the word of God and the deductions of reason, they call themselves *Unitarians*, and affect to consider all other Christians, even their friends the Arians, as *Polytheists*. Modern Unitarianism, as taught by Dr. Priestley, is, however, a very different thing from Socinianism, as we find it in the Racovian Catechism and other standard works of the sect.

SOCINUS, LÆLIUS, the first author of the sect of the Socinians, was born at Sienna in Tuscany in 1525. Being designed by his father for the law, he began very early to search for the foundation of that science in the word of God; and by that study discovered that the Romish religion taught many things contrary to revelation. Being desirous of penetrating farther into the true sense of the scriptures, he studied Greek, Hebrew, and even Arabic. In 1547 he left Italy, to go and converse with the Protestants; and spent four years in travelling through France, England, the Netherlands, Germany, and Poland, and at length settled at Zürich. He by this means became acquainted with the most learned men of his time, who testified by their letters the esteem which they had for him; but as he discovered to them his doubts, he was greatly suspected of heresy. He however conducted himself with such address, that he lived among the capital enemies of his opinions, without receiving the least injury. He met with some disciples, who heard his instructions with respect; these were Italians who had left their native country on account of religion, and wandered about in Germany and Poland. He communicated likewise his sentiments to his relations by his writings, which he caused to be conveyed to them at Sienna. He died at Zürich in 1562. Those who were of sentiments opposite to his, and were personally acquainted with him, confess that his outward behaviour was blameless. He wrote a paraphrase on the first chapter of St. John; and other works are ascribed to him.

SOCINUS, Faustus, nephew of the preceding, and principal founder of the Socinian sect, was born at Sienna in 1539. The letters which his uncle Lælius wrote to his relations, and which infused into them many seeds of heresy, made an impression upon him; so that, knowing himself not innocent, he fled as well as the rest when the inquisition began to persecute that family. He was at Lyon when he heard of his uncle's death, and he departed immediately to take possession of his writings. He returned to Tuscany; and made himself so agreeable to the grand duke, that the charms which he found in that court, and the honourable posts which he filled there, hindered him for twelve years from remembering that he had been considered as the person who was to put the last hand to the system of divinity, of which his uncle Lælius had made a rough draught. At last he went into Germany in 1547, and paid no regard to the grand duke's advices to return. He stayed three years at Basel, and there studied divinity; and having adopted a set of principles very different from the system of Protestants, he resolved to maintain and propagate them;

for which purpose he wrote a treatise *De Iesu Christo Servatore*. In 1579 Socinus retired into Poland, and desired to be admitted into the communion of the Unitarians; but as he differed from them in some points, on which he refused to be silent, he met with a repulse. He did not however cease to write in defence of their churches against those who attacked them. At length his book against James Paleologus furnished his enemies with a pretence to exasperate the king of Poland against him; but though the mere reading of it was sufficient to refute his accusers, Socinus thought proper to leave Cracow, after having resided there four years. He then lived under the protection of several Polish lords, and married a lady of a good family; but her death, which happened in 1587, so deeply afflicted him as to injure his health; and to complete his sorrow, he was deprived of his patrimony by the death of Francis de' Medici, great duke of Florence. The consolation which he found in seeing his sentiments at last approved by several ministers, was greatly interrupted in 1598; for he met with a thousand insults at Cracow, and was with great difficulty saved from the hands of the rabble. His house was plundered, and he lost his goods; but this loss was not so uneasy to him as that of some manuscripts, which he extremely regretted. To deliver himself from such dangers, he retired to a village about nine miles distant from Cracow, where he spent the remainder of his days at the house of Abraham Blonski, a Polish gentleman, and died there in 1604. All Faustus Socinus's works are contained in the first two volumes of the great collection entitled *Bibliotheca Fratrum Polonorum*.

SOCOTARA, an island of the Indian Ocean, about forty leagues to the eastward of Cape Guardafui. It is mountainous, with a bold shore and excellent harbours, and the inhabitants are in general civil to strangers. The principal produce is aloes. The town has a handsome appearance, the houses being built of stone, and some with several mosques. The residence of the king is in long. 53. 33. E. Lat. 12. 39. N.

SOCRATES. The name of Socrates is familiar to every one among his earliest classical recollections. Who has not heard of the Athenian sage, the great moralist of heathenism, and his persecution and constancy even to death? There is no name indeed which stands forth more conspicuously in the history of the philosophy, or of the religion, or of the general civilization of the ancient world. It marks a distinct era in the progress of the human race. The character of a great period in the history of man is concentrated, in fact, in the life and teaching of this extraordinary individual; and his name accordingly has descended to us with all the importance of the crisis itself at which he flourished; recommended as it is to our affection and admiration, not so much by the characteristics of his personality, as by the tradition of his influence and authority.

For when we come to consider his particular biography, we find our attention arrested by little that belongs merely to the individual. We read of a long life passed for the most part in uniform tenour within the walls of his native Athens; and until we come to its tragical close, scarcely distinguished in point of incident from that of the mass of his contemporaries. When, again, we ask for writings from which, as from the proper mirror of the philosopher's mind, we may collect some express lineaments of his character and teaching, we find nothing even on this ground on which our curiosity can fasten; so little have we derived that interest, which the mention of Socrates now awakens, from himself immediately; and so much, on the other hand, are we indebted for our acquaintance with this philosopher to a popular feeling preserving and handing down to us the name which represents the thought and character of an age.

The conjuncture of events at the time of Socrates was

Socotara,
Socrates.

Socrates. peculiarly favourable to the development of such a character. Socrates, born at Athens in the year 469 or 470 B.C. grew up to manhood during those years when Athens, standing on the proud eminence of her victories of Marathon and Salamis, was consolidating her power as a sovereign state and seat of empire. In the course of the fifty years which intervened between her triumphant resistance to the Persian invasion and the commencement of the Peloponnesian war, Athens, like Rome in her struggle with her Italian neighbours, had gradually converted her allies in the islands and on the coasts of Asia Minor and Thrace into dependent subjects and tributaries. But Athens had not, like Rome, the prudence to combine these scattered members of her empire, elements of discord and trouble as much as of strength to the sovereign state, by the free communication of the rights of citizenship. Nor indeed could this wise expedient have availed in the case of Athens as in that of Rome. For the states over which the empire of Athens extended were either independent governments reluctantly submitting to her yoke, or the weak dependencies of a rival power, and indisposed to acknowledge the sovereignty of Athens but so long as that power wanted the vigour and the enterprize to head a coalition against the common oppressor. There were thus in the very constitution of the Athenian empire, materials of jealousy and disunion, which no line of conduct but the impolitic one of surrendering an arbitrary rule into the hands of the people who had groaned under it, could long have kept from explosion. And, in fact, it was not the policy of Athens (masterly as that policy was under the hands of her great leaders) which sustained her empire for more than fifty years, so much as the inertness of her great rival, Lacedemon, and the difficulty of bringing the several grievances of the subject-states to bear on some decisive point, capable of influencing the movement of the whole in a strenuous concerted effort of resistance. At length we see this effort in the outbreak of the Peloponnesian war, as well as the difficulty of it in the complicated diplomacy by which that great movement was preceded, and in the reluctance of Lacedemon to bring home to herself the necessity of exertion.

But, whilst Athens was thus aggrandizing herself against a day of retribution from the insulted states of Greece, she enjoyed the sunshine of her day of empire, in the brilliant assemblage, which she then witnessed within her walls, of the great, and the learned, and the eloquent, from all parts of Greece.¹ While her arms and her enterprize were setting foot on every sea and land, her attractiveness as a home of genius and civilization, was evidenced in the number of strangers frequenting her porticoes, and groves, and theatres, and temples, and the houses of her nobles. During thirty years of this period of glory, the philosopher Anaxagoras was employed in propagating there the doctrines of the Ionic school, honoured by the patronage of her great men, and the revered master of her choicest spirits in the newly-acquired taste for philosophical inquiry. During, also, a considerable portion of the same period, the sophist Prodicus was domesticated within her walls, surrounded by crowds of admiring pupils from the highest ranks of her citizens, eagerly catching the inspiration of that rhetorical ability for which he was famed. Occasionally, too, amongst the distinguished visitors of the city, might be seen

other illustrious professors of the day, also familiarly known by the name of sophists, then a complimentary designation,—Protagoras of Abdera, Gorgias of Leontium, Hippas of Elis,—drawn there by the demand for that literary merchandize, of which they claimed the monopoly. There also were now collected, as in a school of all arts, the great masters of the drama, of sculpture, and painting, and music, and the gymnastic exercises. So that Athens, at this time, contained within her own bosom abundant resources for the enlargement of the mind, whether in the eminent men who formed her society, in the lectures and conversation of the professors of science, or in noble works, the specimens and examples of what genius could effect. Athens contained, also, doubtless, much to enervate and corrupt the moral judgment, whilst she presented every thing to exalt the imagination and refine the taste. Her political institutions, well-balanced as they had been left by Solon, were now violently disturbed. In the course of these years of imperial greatness and prosperity, they received a large infusion of that licentious spirit, which the naval successes of the Athenians had engendered in the lower order of the citizens,² and the flattery of successive demagogues had fostered and diffused through the whole of the state. Now, also, faction divided the ties of family and kindred, and formed associations of the people for every lawless purpose of private ambition and cupidity. Their highest and purest court,—one principal anchor of the state, according to the intention of their great legislator,³—the Areopagus, was mutilated in its powers. And whilst numerous courts of law, thronged by their hundreds of judges, chosen by lot from the whole body of citizens, were constantly open,⁴ and an idle populace were encouraged, by pay from the public treasury, to attend on the business of these courts, the functions of the legislative and deliberative bodies were virtually suspended. The peremptory power of these judicial committees, in which the people at large felt and exercised a despotic authority, became the real executive of the state. Then came into intense activity the vile system of sycophancy,—a system, under which the life and property of the wealthy were at the mercy of every needy adventurer who could speak to the passions of the people, and earn a livelihood for himself by a career of successful prosecutions.

Nor was public corruption unattended by its usual evils of private luxury and debauchery. At this time too, there might be observed in the heart of a city which prided itself on its pious feeling,⁵ and amidst the frequency and splendour of festivals and external rituals of religion,⁶ a profane scepticism with regard to the fundamental principles of religion and morality. A spirit of self-conceit and of presumption of knowledge, already natural to the Athenians, had now widely spread among the people; and every one was by turns dogmatist or sceptic,—according as it was his own opinion that he asserted,—or as he might display his ingenuity in questioning some received principle, or disputing some opinion proposed by another.

Add to these circumstances, the effect of a large slave population, the degraded ministers to the wants and the wealth of an insolent body of citizens, and of a number of resident foreigners engaged in carrying on the manufactures and trade of the city, paying a tax for their protection, and contributing to the military strength of the state, though excluded from its franchise. The slave, indeed, and the

¹ Isocrat. Panegy. Καὶ τὸ πλῆθος τῶν ἀφικνουμένων ὡς ἡμᾶς τοσοῦτον ἐστίν, κ.τ.λ. p. 59.

² Aristot. Polit. ii. 9, τῆς ναυαρχίας γὰρ ἐν τοῖς Μηδικαῖς ὁ δῆμος αἰτίος γενόμενος ἐφρονηματίσθη, κ.τ.λ.

³ Plutarch. Solon, 19, οἰόμενος ἐπὶ δυοὶ βουλᾷς ὥσπερ ἀγκύραις ὁρμῶσαν, ἥττον ἐν σάλῳ τὴν πόλιν ἔσεσθαι, κ.τ.λ. Tom. i. p. 352, ed. Reiske.

⁴ Aristoph. Nub. 208, αἶδε μὲν Αῠθῆναι. Στ. τί σὺ λέγεις; οὐ πείθομαι, ἐπεὶ δικαστὰς οὐχ ὁρῶ καθημένους.

⁵ Soph. Œd. Col. 1006, εἰ τῆς γῆ θεοῦς ἐπίσταται τιμᾷς σεβίζειν, ἥδε τὸν ὕπερ φέρει.

⁶ Xenophon, in his *Memorabilia*, i. c. 4, gives an instance in Aristodemus of one who not only had a contempt for all religion, but even derided those who concerned themselves with it.

Socrates. foreigner, lived more happily at Athens than at Lacedæmon, or perhaps any other city of Greece, especially during a time of war, when their services were needful to the state.¹ Slavery, therefore, acted probably less injuriously on the character of the Athenian master, than it did elsewhere in Greece. It was tempered by the social humour of the people. But the facility thus afforded to the citizens of living in indolence and ease, and abandoning all domestic employment for the excitement of the public assemblies, and the courts, and the spectacles, naturally induced a neglect of the private and domestic duties. There is reason to believe, that whilst the Athenians appeared in the face of the world the most light-hearted of men, they were secretly unhappy in their homes; living in listlessness from day to day on the alms of their public pay; many of them reduced from affluence to poverty through the loss of lands and property by the ravages and pressure of war, and yet unable or unwilling to use the necessary exertions to relieve themselves from their distress. It is evidently no singular instance which Xenophon has given of this state of things at Athens, when he tells us of Aristarchus complaining to Socrates of the number of poor female relatives who, from losses in the course of the Peloponnesian war, were thrown on him for support. The difficulty which Aristarchus felt, was, that he could not expect persons who were free-born and his own kindred, to undertake any manual labour, so as to assist in maintaining themselves. Happily, however, he adopts the friendly suggestion of Socrates, and makes the experiment of setting them actively to work. The experiment succeeds; and thus contentment and cheerfulness are introduced to a home where before all was gloom and mutual suspicion.²

In the meantime, a great number of mechanics and tradesmen had risen to wealth and importance, in consequence of the demand for every species of labour and trade, resulting from the multiplied population of the city and its numerous foreign dependencies and connexions, and, in particular, from the magnificent public works carried on during the administration of Pericles. All this while, Athens was becoming more and more a mercantile community, in the midst of strong aristocratic prejudices, still surviving, and rendered, indeed, more intense by the opposition growing up around them. In many instances, the older families would be declining in wealth, exhausted by the burthens of the state or the extravagance of individual expenditure; whilst new families, the creations of successful trade and enterprize, would be obtaining influence by the force of their wealth, and encroaching on the privileged ground hitherto occupied only by right of birth. It may be easily conceived, therefore, that the mass of the society of the city would be now all fermentation and restlessness; the one class pushing their interests and their claims to equality founded on their personal title, whilst the other obstinately clung to the exclusiveness and the pride of hereditary right.

But we shall best judge of the distempered state of the social atmosphere of Athens, by adverting to the character of female society as it existed there. It has often been remarked, as the glory of modern and Christian civilization, that it has restored woman to her due place in the scale of social importance, and thus most effectually chastened and elevated the general intercourse of human life. In a country so essentially social as Greece, and especially at Athens, it was practically impossible to impose on the women the absolute

seclusion of eastern despotism. Still it was even at Athens considered the rule of propriety, that the wives and daughters of citizens should live in the strict privacy of their homes, and be known and noticed as little as possible among the other sex, even for their virtues.³ But whilst the virtuous matron was excluded from the social circles, the place which she should have held in Athenian society was filled by other females, strangers to family ties, and attracted to Athens by the licentiousness and wealth of an imperial city. The union of high intellectual endowments, and a masculine dignity of understanding, in some distinguished individuals of this class, with the graces of female loveliness, appealed with a powerful interest to the sensual elegance of Grecian taste. We find, accordingly, at Athens, at this time, forming, as it were, the female court of the sovereign people, the Milesian Aspasia, and others of less name, living in the profession of a scandalous course of life, not only without shame, but even in the enjoyment of public respect. It was not the general of the commonwealth only that felt the spell of the charms of Aspasia, but grave philosophers resorted to her house; and even the ladies of private families, in violation of the restrictions of custom, were taken there by their friends; all eager to hear those interesting conversations, and lectures in political and rhetorical science for which she was famed.⁴ We may judge how deeply corrupted must have been the standard of public opinion in Greece, when female profligacy could thus veil itself from the eye of moral observation, under the graces of splendid accomplishments of mind and person. So thoroughly had refinement of intellectual taste and of manners, together with the grossest impurity of morals, pervaded the whole society of Athens, that even those who were elevated above the world around them in talents, and strength of character, and kindness of disposition, as Socrates was, imbibed in some measure the poison of the infected atmosphere which they breathed.

Such, then, was that state of things in which Socrates was trained, and which will greatly account to us for that peculiar form which the character of his philosophical teaching exhibits. For he was ever an Athenian instructing Athenians. He spoke as one fully conversant with the habits of thought and action of his countrymen; as knowing what kind of instruction they most needed, and by what mode of address he might best win their attention. We might expect, therefore, to see in him some leading traits of the Athenian civilization of his time; a teaching, admirable indeed in its main features, but bearing, at the same time, some marks of that corrupt state of society which called it forth, and to which it was immediately addressed.

The son of Sophroniscus a sculptor, and Phænareté a midwife, and himself brought up in his father's art, he yet enjoyed those advantages of mental culture and social refinement which were common to every citizen of the democratic Athens. The meanness of his birth and his poverty, much as high birth and wealth were esteemed there, would not exclude him from familiar intercourse with persons of the highest rank and consideration in the state. Nor, indeed, could the advantages of education be restricted to a privileged few, where every one lived in public, and where knowledge was for the most part acquired and communicated by conversation and oral discussion.

If, in the general relaxation of discipline at Athens, the citizen was no longer obliged to submit himself to a prescribed course of education under the eye of the state, and it was

¹ Aristoph. Nub. 5, ἀπόλοιτο δὴτ', ὃ πολέμῳ, πολλῶν ὄννεκα ὅτι οὐδὲ κολάσαι ἔξεστί μοι τοὺς οἰκέτας.

² The story is beautifully told by Xenophon in his simple manner in the *Memorabilia*, book ii. chapter 7. See also Mem. ii. 8.

³ Thucyd. ii. 45, τῆς τε γὰρ ὑπαρχούσης φύσεως μὴ χείροσι γενέσθαι ὑμῖν μεγάλη ἡ δόξα, καὶ ἥς ἂν ἐπ' ἐλάχιστον ἀρετῆς περίῃ φόγῳ ἐν τοῖς ἄρσεσι κλέος ᾖ.

⁴ Plato, Menex.—Xenoph. Mem. ii. 6.—Plutarch. Pericles. 24. Καὶ γὰρ Σωκράτης ἐστὶν ὅτε μετὰ τῶν γνωρίμων ἐφοῖτα. καὶ τὰς γυναῖκας ἀκροασομένας οἱ συνήθεις ᾗγον ὡς αὐτὴν, κ.τ.λ. Tom. i. p. 638, Reiske.

Socrates.

left to each person to avail himself, or not, of the sources of instruction presented in the intellectual society of the city, Socrates was not a person to neglect the advantages placed in his way. Money he had not, to pay to the Sophists, the great masters of his day. But he had from childhood an inquisitive mind. He felt that he was thrown on his own resources of thought, and that he must be his own master in the art of education. And to this great object he appears to have bent, from the earliest time, all the powers of his energetic mind, making it his constant employment to inquire from every one,¹ and collect on every occasion, some hint towards the right prosecution of it. We may picture to ourselves the young Socrates, resembling the Socrates of mature life, freely entering into conversation with all to whom he had access; feeling and acknowledging his own ignorance; listening attentively to all that he heard; weighing and discussing it in his own mind with patience and acuteness; and not resting until he had traced it out in all its bearings to the utmost of his power. Thus would he gradually form and strengthen that faculty of observation, and that analytical acumen for which he was afterwards so eminently distinguished.

Nor has Plato improbably put a prophecy of his future eminence in the mouth of one of the great masters of the day, when he makes Protagoras say of him, with the self-complacency of the man of established reputation: "For my part, Socrates, I commend your spirit, and the method of your reasoning; for whilst in other points I am no bad sort of person, as I think, I am the farthest from being an envious one. For concerning you in particular, I have already observed to many, that of all I meet, I admire you by far the most; of those of your own age, even to the extreme; and I say too, I should not be astonished if you were to turn out a man of celebrity for philosophy."² To the same effect is the story, that his father, being at a loss how to educate him, consulted the Delphic oracle, and was advised to leave him entirely to his own bent, inasmuch as he had a director in himself superior to a thousand teachers.³ The simple interpretation of what is here thrown into the form of marvel probably is, that he gave, even when a child, striking indications of a devotedness to those studies which became the business of his manhood.

The notice of a wealthy individual of Athens, the excellent Crito, appears to have been early attracted to Socrates. Crito was of about the same age as Socrates;⁴ and an attachment to the pursuit of philosophy, and an admiration of the character of Socrates, naturally led to that intimacy which he now commenced with the young philosopher, and steadily maintained through his subsequent life. Through him Socrates was relieved from the necessity of earning his livelihood by the profession of a sculptor; or, as Laertius expresses it, "was raised from the workshop."⁵ Sculpture, indeed, was in high honour at Athens, especially at this time. For Phidias, enjoying the protection of Pericles, was now adorning the city with the immortal productions of his own chisel, as well as other noble works of art executed under his taste and direction. But to follow up the profession with success, required a devotion of mind and hand that must preclude the opportunities indispensable for the moral student. And though, for a time, Socrates worked at the art,—and with success, if a statue of the Graces in the citadel of Athens, attributed to him, were really his workmanship;⁶—we may imagine how distasteful the occupation, however intellectual in itself, must have been to a mind, so eager for observation on living man, so intent on mental and moral phenomena, as that of Socrates; and how gladly he would ex-

change the labour of his paternal art for that philosophic leisure which the friendship of Crito held out to him. Socrates.

The world of that day reproached the philosophers with servility, taunting them with being ever seen at the "gates of the rich." In some instances, the reproach may have been just. But in general, the fact was the reverse. Their society rather was courted by the great and wealthy, who were proud of the reputation of being patrons of philosophy. To Socrates, indeed, the patronage of a man of wealth would be peculiarly acceptable, not so much for the means of subsistence, about which he was absolutely thoughtless and indifferent, as for the society itself to which he would thus be introduced, and the opportunity of carrying on his researches into philosophy, both by books and by the oral instructions of its living professors. To him it would be the very means by which he would enlarge his field of moral observation. The social evenings of Athens were the natural sequences of the mornings of the agora, and the courts, and the council, and the assembly. They prolonged in festive conversation that strife of words and competition of argument, which had been begun in the busy and serious discussions of the morning, and of which the last murmurs had scarcely died away on the ear of the assembled guests. For Athenian life was a life of constant excitement. What Demosthenes observed an hundred years afterwards, and an apostle four hundred years later still,—that the Athenians did nothing but go about and ask the news of the day,—was a characteristic of the people already strongly developed at this period of their history. Socrates, who, in his own person, gave a philosophical cast to this inquisitive spirit, would be peculiarly interested by such opportunities of exercising it as were presented in the animated encounters of the symposium. There he would see human nature displayed in some of its most striking forms. There he would meet the citizen full of years and honours, experienced in the arts of government and diplomacy, and in the service of the state by land and sea; the poet flushed with his victories in the dramatic contest; the sophist armed at all points for the display; the philosopher expounding his theories; the orator, the idol of the people in his day; the courtly patron of literature; and a circle of young men, the flower of the highest rank in the state; each bearing his part in the free and lively interchange of thought, emulously provoking one another to discussion, and contending for the mastery in the conflict of debate.

By such society Socrates would be effectually prepared for that active enterprise of philosophy, which formed the whole engagement of his life. In the meagre information handed down to us respecting the details of his history, we are not able to ascertain at what precise period of life he began his career of public teaching, or at least attracted notice as the philosopher of Athens. The transition would probably be gradual, from the youthful inquirer, to the mature and expert teacher of others. This transition would be the less perceptible in the case of Socrates, from the circumstance, that he never professed to *teach*, even when he was most actively employed in teaching; but still, at the last, as he had done from the first, merely to *inquire*.⁷ For his part, he disdained the *profession* of philosophy. He was disgusted with the vain pretension advanced by the Sophists, of being masters of every science, and capable of imparting instruction on any given subject. He accordingly set out with the antagonist position, that he *knew nothing*: that his only wisdom, if he possessed any beyond other men, consisted in his being *aware* of his real ignorance, whilst others ignorantly presumed on the possession of a knowledge which they had not. His teaching, therefore, was only a continuation of the process of educa-

¹ Plato, *Laches*, p. 186, c., ἐγὼ μὲν οὖν, κ.τ.λ. p. 176, Bip. ed.

⁴ Plato, *Apol.* p. 78, ἑμὸς ἡλικιώτης.

⁶ Xenoph. *Mem.* i. 2, οὐδὲ πώποτε ὑπέσχετο διδάσκαλος εἶναι τόντου.

² Plato, *Protag.* Op. iii. p. 193.

⁵ Plutarch, *de Gen. Socr.*

³ Diog. Laert. in vit. ii. 5.

⁷ Diog. Laert. ii. 5. Pausanias, i. 22; ix. 35.

Socrates. tion of his own mind, by extending it to the minds of others. He was fond of describing it as an *examination* or *scrutiny* of the mind; a method of finding out the real condition of each mind, and so of preparing it for the due exercise of its powers in the practical emergencies of human life. He saw that the evils of life arose, in great part, from the wrong judgments of men,—from their mistaking their own powers, presuming on their knowledge, and ability, and the truth of opinions adopted without inquiry. He endeavoured then to effect the cure of human error and unhappiness by a reformation of the intellect. The first step towards this would be taken, if men could be only divested of this vain self-confidence; if they could be brought to *suspect* that they might be mistaken in their judgments, and so to *question* themselves. This preliminary labour was employment enough for any one man's life, especially in a society such as that of Athens, so entirely infected with the sophistical leaven. Socrates wisely confined his exertions to this simple object. He is content to excite inquiry,—to provoke discussion,—and thus to suggest the necessity of self-discipline in order to right judgment. He does not, like other philosophers, quit the seclusion of a study, or the field of foreign travel, to come forth to the world the accomplished teacher of the accumulated wisdom of years of solitary thought and reflection. Whilst philosophizing in the agora and the streets of Athens, in the workshops of the artizan, or at the banquets of the rich, he is still employed in the work of *disciplining* the mind. Thus he passes on insensibly from the education of himself to the education of others, and it is difficult consequently, or rather impossible, to say in his case, where the character of the learner ends, or where that of the philosopher and teacher begins.

Yet, entirely as Socrates disregarded all positive knowledge, and threw himself on the resources of a shrewd and extensive observation of human nature, we must not suppose that he neglected to inform himself in the existing systems of philosophy, and the particular sciences as they were then understood and taught. There is reason to believe, that he had accurately studied the systems of the early physical philosophers of the Ionic school, as well as the moral and mathematical theories of the Pythagoreans, and the dialectics of the school of Elea. Without supposing him so deeply versed in the doctrines of the several schools, as would be inferred from his exact discussions in the dialogues of Plato, there is still ample evidence, from the more direct account of Xenophon, that he was by no means ignorant of them. He had doubtless read much,¹ as well as observed much, when he commenced his philosophic mission. Xenophon indeed tells us that Socrates considered the physical and dialectical theories of his predecessors as unprofitable. But he takes care to add, that Socrates was not unacquainted with these theories. And in particular, as to the sciences of astronomy and geometry, he thought the attention of the student wasted in investigating their more abstruse theorems. But he was able (as Xenophon further observes), to speak on the subjects of these sciences also from his own knowledge of them.²

Nor are we to suppose that, whilst he had properly no master in that line of philosophical study which he had marked out for himself,³ he had no aid in the cultivation of

his mind, from the living masters of philosophy in his day. The long residence of Anaxagoras at Athens, probably coincides in time with part of the early life of Socrates.⁴ To him, therefore, Socrates would naturally have access, as well as to Archelaus,⁵ his disciple, and the inheritor of his doctrines. If he had no personal intercourse with Anaxagoras, it is at least highly probable, from the testimony of Plato, that he was acquainted with the famous treatise of Anaxagoras, which contained his theory of the universe.⁶ And perhaps we may distinctly trace the early and abiding influence of the lessons of this great philosopher throughout the teaching of Socrates, in his uniform maintenance of the principle of an all-disposing mind, the glory of the system of Anaxagoras.

To the writings of Heraclitus, his attention appears to have been drawn by the poet Euripides; if the anecdote be true, as related by Laertius, that on being asked by Euripides, who had put them into his hand, what he thought of them, he replied, alluding to the studied obscurity of that philosopher; "What I understand is excellent; so also, I suppose, is what I do not understand; only there is need of some Delian diver to reach the sense."⁷ He had also opportunities of conversing with Zeno the Eleatic, and Theodorus of Cyrene; the former eminent for his dialectical skill, the latter the most distinguished geometrician of the time. And though his scanty means precluded his attendance on the professional lectures of Prodicus, the fashionable teacher of rhetoric at that day at Athens, it cannot be doubted that he would on several occasions have been among the company assembled at the house of some wealthy citizen, and there heard from the lips of that accomplished master of language those elaborate oratorical displays which made his name proverbial for wisdom.⁸ With the poet Euripides, indeed, the disciple of Anaxagoras and Prodicus, and who was his senior only by a few years, he appears to have lived in habits of intimacy. With Euripides he would probably often have discussed those ethical topics which the poet so greatly delighted to transfuse into his tragic scenes, and associate with the interest of dramatic incident. They were in fact brother-labourers in the same cause, though in different ways. For whilst Euripides endeavoured to work a reformation of his countrymen, by didactic addresses insinuated through their feelings, amidst the interest of tragic story, Socrates appealed at once to their understandings, and amidst the business or pastime of real life. The envy of contemporaries was prone to attribute the excellence of the poet in some of his dramatic efforts, to the aid of his philosopher-friend.⁹ The truth probably is, that the benefit of their intercourse was mutual; that, whilst the poet's imagination was informed and chastened by the shrewd and severe wisdom of the philosopher, the philosopher also, ever intent on his calling, would enlarge his mind with riches drawn from the genius, and taste, and learning of the poet.

The co-existence of literary and philosophic elegance with the most disgusting coarseness of moral feeling and conduct, in the character of the Athenian courtesan, has been already noticed. To Aspasia, the heroine of her class, as we may call her, when we refer to her influence over Pericles, and the encomiums of her by Plato and others, Socrates is expressly stated to have been indebt-

¹ Xenoph. Mem. i. 6.

² He reckons himself in Xenoph. Conviv. i. 5. among the *αὐτουργοὶ τῆς φιλοσοφίας*.

³ It must be admitted, however, that the chronology of the life of Anaxagoras is very doubtful.

⁴ Archelaus is called both a Milesian and an Athenian. The probability is that he was a Milesian, since philosophy had scarcely yet found a home at Athens.

⁵ See the Phædo, p. 97. The writings of Anaxagoras appear to have been extensively circulated. Socrates is made in Plato's *Apology* to say to Melitus, *οἷε αὐτοὺς ἀπειροὺς γραμμάτων εἶναι, ὥστε οὐκ εἰδέναι ὅτι τ' Ἀναξαγόρου βιβλία τῶν Κλαζομενίου γέμει τούτων τῶν λόγων*.

⁶ Diog. Laert. in vit. ii. 7.

⁷ Plato, Meno, p. 96. *Κινδυνεύομεν, ὦ Μένων, ἐγὼ τε καὶ σὺ, φᾶνλοι τινες εἶναι ἄνδρες, καὶ σέ τε Γοργίας οὐχ ἱκανῶς πεπαιδευκεναι, καὶ ἐμὲ Πρόδικος*. P. 332. Bipont.

⁸ Aristoph. Nub. Diog. Laert. in vit. ii. 5.

⁹ Xenoph. Mem. iv. 7.

Socrates. ed for instruction in rhetoric, as also in other subjects.¹

Whilst Xenophon also introduces him familiarly conversing with Theodota, whom he describes as living in great splendour at Athens, the object of general admiration for her personal charms, and inviting her to become his disciple,²—Plato leads us to believe that Socrates was himself the disciple of another of the same class, the Mantinean Diotimè, who, among her other accomplishments, was distinguished in particular for her skill in the art of divination.³

Instruction in music formed an important part of Athenian education. Socrates, it seems, did not neglect the opportunities which the presence of the great masters of the art in Athens afforded him of learning its principles. Connus accordingly is claimed for him, as his master in music.⁴ Damon, another celebrated musician, though not more eminent in the science which he professed, than as a politician and sophist, was resident at Athens during part of the administration of Pericles, the intimate and counsellor of that great statesman, as well as his instructor in music.⁵ From him also, we are told, Socrates received instruction in the art. By these accounts, however, we may probably understand, not that he became a proficient in the musical art, but that he had listened to Damon as well as to Connus, discoursing on the subject, and studied its theories under them, so far, at least, as music entered into the general pursuit of philosophy.⁶

It should be observed, indeed, that though Socrates strongly discouraged the *presumption* of knowledge in all with whom he conversed, he did not disapprove of the acquisition of particular kinds of knowledge. He communicated whatever he knew to every one that came in his way; and where he was himself unacquainted with any subject, he referred his hearers to those who possessed the information.⁷ He was not in fact opposed to knowledge in itself. He was glad to embrace it wherever it could be found. But he was an enemy to the substitution of mere intellectual acquisitions,—and those often superficial and unreal,—for *education* of the mind and character. He felt, and justly felt, that knowledge by itself was vanity. The tendency of the age was to ascribe value exclusively to mental acuteness and dexterity. Ingenuity and cleverness obtained the merit and the prize of wisdom. His labour was to draw his countrymen from thinking too highly of their boasted knowledge. He wished them to see how greatly they overrated intellectual acquirements,—how much they had yet to learn if they would be real proficient in wisdom.

Socrates indeed appears to have regarded philosophy in the light of a sacred mission, to which he was specially called, rather than of a study and exercise of the mind. This notion of philosophy had already been exemplified by Pythagoras and his followers. But they had realized it by forming themselves into distinct communities or colleges; separating themselves from the world around, by a solemn initiation, and the practice of an ascetic discipline. Socrates, however, had no thought of changing the outward form of society. He did not propose, like Pythagoras, to institute a refuge from the pollutions and misery of the world, or to educate a peculiar brotherhood, who should afterwards act on the social mass. He did not address himself to the few. His school was all Athens, or rather indeed all Greece. Leaving society as it was, he sought to infuse a new spirit

into it, by carrying his philosophy into every department of it. He therefore went about among all classes of people, preferring none, despising none, but adapting his instructions to every variety of condition and character. Thus did he in truth, according to the observation commonly applied to him from the time of Cicero, bring down philosophy from heaven to earth; but not so much by being the first to give a moral tone to philosophy, as by the universality and philanthropy of his teaching. Philosophy in his hands was no longer an exclusive and privileged profession. It no longer spoke as from an oracular shrine, and in the language of mystery. It now conversed with every man at his own home,—submitted to be familiarly approached and viewed without reserve,—and, instead of waiting to be formally consulted by its votaries only, volunteered to mingle in the business, and interests, and pleasures of every-day life.

His manner of life and of teaching is thus described by Xenophon.⁸

“He was constantly in public. For early in the morning he would go to the walks and the gymnasia; and when the agora was full, he was to be seen there; and constantly during the remainder of the day, he would be wherever he was likely to meet with the most persons; and for the most part he would talk, and all that would might hear him.”

The nature of his conversations is thus further reported by the same faithful authority:

“No one ever saw Socrates doing, or heard him saying, any thing impious or profane. For not only did he not discourse about the nature of all things, as most others, inquiring how, what by the sophists is called the universe, consists, and by what laws each heavenly thing is produced; but he would point out the folly of those who studied such matters. And the first inquiry he would make of them was, whether they proceeded to such studies from thinking themselves already sufficiently acquainted with human things; or whether they thought they were acting becomingly in passing by human things, and giving their attention to divine. He would wonder, too, it was not evident to them, that it was not possible for men to find out these matters; since even those who most prided themselves on discoursing of them, did not agree in opinion with each other, but were affected like madmen in relation to one another. For of madmen, whilst some did not fear even the fearful, others were terrified at things not terrible; whilst some were not ashamed to say or do any thing even before the multitude, others objected even to going out into the world; whilst some paid no honour to sacred things, or altars, or any other religious object, others worshipped even stones, and common stocks, and brutes. So of those who speculated on the nature of the universe, whilst some thought that Being was one only, others thought it was infinite in number; whilst some thought that all things were in perpetual motion, others thought it impossible for any thing to be moved; whilst some thought that all things were in a course of generation and destruction, others thought that nothing could possibly be generated or destroyed. He would further consider respecting them thus: whether, as the learners of human things think they shall be able to make practical use of their knowledge for themselves and any one else at pleasure, so also the searchers into divine things hold, that having ascertained by what laws each thing

¹ Xenophon, Mem. ii. 6. Μὰ Δέ, οὐχ, ὥς ποτε ἐγὼ Ἀσπασίας ἤκουσα. ἔφη γὰρ, τὰς ἀγαθὰς προμνηστρίδας, κ.τ.λ. P. 101. Plato, Menexenus, p. 235. Καὶ ἐμοὶ μὲν γε, ὦ Μενέξενε, οὐδέν θαυμάζον οἶω τ' εἶναι εἰπεῖν, ὅτι τυγχάνει διδάσκαλος οὖσα ὅν πάννυ φαύλη περὶ ῥητορικῆς, ἀλλ' ἤπερ καὶ ἄλλους πολλοὺς καὶ ἀγαθοὺς ἐποίησε ῥήτορας, ἕνα δὲ καὶ διαφέροντα τῶν Ἑλλήνων, Περικλέα τον Ξανθίππου. Μ. τίς αὐτῇ; ἡ δὲ δηλονότι Ἀσπασίαν λεγεις; Σ. λέγω γάρ; καὶ Κόννον γε τὸν Μητροβίου. οὗτοι γὰρ μοι δυο εἰσὶ διδάσκαλοι· ὁ μὲν μουσικῆς, ἡ δὲ ῥητορικῆς. P. 277. Bipont.

² Xenophon, Mem. iii. 12. Ælian. Var. Hist. xiii. 31.

³ Plato, Menexenus.

⁴ Diog. Laert. in vit. ii. 5. 15. Laertius says that Socrates learned to play on the lyre.

⁵ Mem. i. 1. 10; also Plutarch, *Utrum seni ger. Resp.*

⁶ Plato, Conviv. p. 201. op. t. 10. p. 227. Bipont.

⁷ Plutarch in Pericl. op. t. i. p. 594. Reiske.

⁸ Xenoph. Mem. iv. 7.

Socrates. is generated, they shall be able to produce at pleasure winds, and waters, and seasons, and whatever else of the kind they may want; or whether they have no such expectation, but it suffices them only to know how every thing of this kind is generated. Such, then, was his manner of speaking about those who busied themselves with these matters. But, for his part, he was ever discoursing about human things, inquiring what was pious, what impious, what honourable, what base, what just, what unjust, what sobriety, what madness, what courage, what cowardice, what a state, what a statesman, what a government of men, what the character of a governor; and about other subjects, which, by being known, would make men honourable and virtuous, whilst those who were ignorant of them, would justly be called slavish."

Xenophon has thus fully touched the character of the teaching of Socrates in its leading points, and the nature of his constant occupation at Athens. The intermissions of military service appear to have been the only occasions of any variation in this uniform course of life. No other country had any charms for him, as no other afforded such rich opportunities of conversing with men, and studying human nature.¹ His activity was essentially different from that either of his predecessors or successors in the path of philosophy. They travelled from place to place searching for knowledge, storing their minds with various observations, and making philosophy their formal business. Socrates, as he had no stated school or place of audience, so he had no design of framing any system of philosophy, or of enlarging the researches and discoveries of former philosophers, or of pursuing knowledge as an ultimate object. He regarded himself as called by the voice of Deity, to undertake the reformation of men, and especially of his fellow-citizens, as constituting his proper sphere of duty, from their corruptions of sentiment and conduct. He stood, therefore, by the great stream of human life which was ever flowing at Athens, and watched its course. He is said once to have visited Samos in company with Archelaus, the disciple of Anaxagoras, and also to have gone to the Pythian and the Isthmian games. With these exceptions, and those of the occasions of military service abroad, he appears to have constantly remained at home, unattracted from the town, the seat of his philosophic mission, by invitations even to the courts of princes. In vain did Scopas of Cranon, and Eurylochus of Larissa, offer him money, and invite him to visit them.² He could refuse also the hospitality of Archelaus, king of Macedonia, the same with whom the poet Euripides found a kind and honourable refuge in his old age, from the envy of his countrymen, and domestic grievance. His refusal of the invitation of Archelaus is said indeed to have been accompanied with the declaration of his feeling, that he could not brook the acceptance of a favour which it was entirely out of his power to return.³ Nay, so entirely engrossed was he in the work to which he had devoted himself, that he was a stranger, as Plato represents him, even to the immediate neighbourhood of the city. The banks of the Ilyssus, even then

classic ground, rich with legendary associations, could not seduce him from the agora and the crowd; so that he seemed scarcely at home beyond the walls of Athens.⁴

No Athenian, however, could decline the military service of the state. And this service, at the time of Socrates, often engaged the citizen in hazardous enterprizes and long absences far from his home. The first occasion on which Socrates is related to have served, was in the Chersonese at Potidæa, just before the opening of the Peloponnesian war. The service in which the Athenian soldiers were engaged here was one of great hardship. It was in the winter season, and the climate in those parts was most severe. Amongst those who distinguished themselves by their resoluteness and gallantry, none was so conspicuous as the philosopher. Whilst others were clothing themselves with additional garments, and wrapping their feet in wool, he was observed in his usual dress, and walking barefoot on the ice, with more ease than others with their shoes. Nor even amidst these circumstances, did he merge the character of the philosopher in that of the soldier. He was seen one morning at sun-rise fixed in contemplation. At noon he was in the same position, and still in the evening, and so continued through the night, until the sun-rise of the following day. Such, too, was his bravery in the engagements at Potidæa, that he earned for himself the prize of distinction, but readily sacrificed his claim to the wishes of the generals, in favour of a more illustrious candidate in the person of Alcibiades. Alcibiades himself would have refused the honour as due rather to Socrates; for to the unwillingness of Socrates to leave him wounded on the field, he had been even indebted for his own life, and the preservation of his arms, after the battle. But the philosopher, with a true magnanimity, insisted on the award of the generals.⁵

The next occasion of military service, in which he was scarcely less distinguished than at Potidæa, was in the eighth year of the Peloponnesian war, at the battle of Delium in Bœotia. The battle was an unsuccessful one to the Athenians, and they were forced to retreat in disorder. Alcibiades was also present on this occasion, and overtook Socrates in company with Laches, one of the generals, on the way. He was on horseback, and comparatively therefore out of danger, whilst they were on foot. He had opportunity, therefore, of admiring the presence of mind which Socrates displayed on the occasion, even beyond Laches, and the steadiness and vigilance with which he kept the enemy from pressing upon them, and so secured their retreat.⁶

These incidents seem to rest on indisputable evidence. The account of them is put into the mouth of Alcibiades by Plato, in that most ingenious of his dialogues, the *Banquet*. The very form in which they are introduced, related as they are by an eye-witness, and that witness Alcibiades, the person, next to Socrates himself, most interested in them, may justly be regarded as giving a sanction to their history, independent of the fictitious circumstances of the dialogue.

The third occasion on which Socrates served as a soldier

¹ Plato, *Laches*, 187, e. "Ου μοι δοκεῖς εἰδέναι ὅτι ὁ δὲ ἀνὴρ ἐγγυτάτω Σωκράτους ἢ λόγῳ, ὡς περ γένει, καὶ πλησιαζῇ διαλεγόμενος, ἀνάγκη αὐτῷ . . . περιεργόμενον τῷ λόγῳ, μὴ παύσασθαι ὑπὸ τοῦτου πρὶν ἐμπέσῃ εἰς το διδόναι περὶ αὐτοῦ λόγον, ὅτινα τρόπον νῦν τε ζῇ, καὶ ὅτινα τὸν παρεληλυθότα βίον βεβιώκεν, κ. τ. λ. P. 180.

² Diog. Laert. in vit.

³ Plato, *Phædr.* 230. Σὺ δὲ γε ὃ θαυμάσιε, ἀτοπώτατός τις φανῇ· ἀτεχνῶς γὰρ ὁ λέγεις, ξεναγουμένῳ τινὶ καὶ οὐκ ἐπιχωρίῳ ἔοικας· ὅντως ἐκ τοῦ ἄστεος οὐτ' εἰς τὴν ὑπερορίαν ἀποδημεῖς, οὐτ' ἐξω τείχους ἔμοιγε δοκεῖς τοπαράπαν ἐξεῖναι. ΣΩ. Συγγίνωσκε δὴ μοι, ὃ ἄρισε, φιλομαθὴς γὰρ εἰμι· τὰ μὲν οὖν χωρία καὶ τὰ δένδρα οὐδὲν με θέλει διδάσκειν, οἱ δ' ἐν τῷ ἄστει ἄνθρωποι. P. 287; also *Crito*, p. 120.

⁴ Aristot. *Rhet.* ii. 23.

⁵ Plato, *Conviv.* 220, a. p. 266; also *Charmides*.

⁶ Plato, *Conviv.* p. 270. The story is again alluded to by Plato, in the dialogue, *Laches*. Laches is made to say that he had had experience of the actions of Socrates, and reminds Socrates of the day of their common danger, ἢ μετ' ἐμὸν συνδιεκινδύνευσας, κ. τ. λ. P. 182. Laertius says that Socrates saved Xenophon, who had fallen from his horse in the battle of Delium, (in vit. Soc. ii. 5-7.) But this cannot be true, as Xenophon would be much too young at that time for military service. In the *Deipnosophists* of Athenæus, (v. 55), doubt is thrown on these accounts of the military service of Socrates, and instances are given of the historical inaccuracy of Plato. The objections, however, as there given, are evidently thrown out in the way of discussion, and not with perfect seriousness, as if the speaker really thought them of weight.

Socrates. was again in Thrace, at Amphipolis,¹ in the same year as that of the unfortunate expedition to Delium. No particulars are mentioned of this adventure. But the fact itself is sufficiently attested. Nor, though it follows immediately on the affair of Delium, is it improbable on that account. For at this busy period of the war, when the Athenians were making demonstrations of their power, by the presence of their forces in different places at once, and when Brasidas was pushing his successes against them in Thrace, no individual of the military age, (and Socrates was not more than forty-six or forty-seven years of age at this time), would enjoy any long interval of relaxation from foreign service.

With these exceptions, Socrates appears then to have constantly resided at Athens. All this time, throughout his whole life indeed, he lived in great poverty, content with the least that might suffice for mere sustenance and clothing from day to day.

Yet it was no artificial, and melancholy, and fanatical life that he led. He accustomed himself to a strict moderation, not with any view to the mortification of the body, or as thinking that abstinence was in itself a virtue, but in order to self-command; by rendering himself as independent as possible of the circumstances of the body, to disencumber the soul of every burthen and obstruction to its free operation. There was nothing, indeed, of austerity in his life or manner. He might be seen walking barefoot, but it was not for the pain that it might inflict. It was only that he might bear cold and privations of every kind the better, and suffer the less inconvenience when exposed to necessary hardships, and require the less for his ordinary subsistence. So far was he from studying a discipline of bodily severity for its own sake, that he was observed at times mingling in the social festivities of his fellow-citizens with the full freedom of Athenian conviviality, and shewing that he could bear excesses which mastered others, without losing his self-command.²

One account, indeed, but not a very credible one, as it rests on the authority of Aristoxenus, an invidious writer, states that he was supported by the alms of friends, contributed from time to time for his relief. With his very limited wants, and his ready access to the house of Crito and other liberal patrons of philosophy at Athens, he would not have to depend on this precarious charity. The pittance which sufficed for the humblest citizen would suffice for him. He is said to have inherited a patrimony of seventy or eighty minæ.³ But this sum, it is added, he lost (though the time is not stated when the loss occurred) by the failure of the person with whom it had been placed at interest. He possessed also a house in Athens; and he was able, however scantily, to support a family. So that we cannot suppose he was absolutely destitute of all resources of subsistence. He appears then rather to have voluntarily renounced every kind of worldly possession, so far as his own personal comfort was concerned, than to have been absolutely reduced to want by the pressure of circumstances. Poverty, in fact, was his profession, and not the mere necessity of his case. If he prided himself in any thing, it was in his avowal of his contempt for riches, and disregard of domestic interests and comforts, in contrast with the general habits of an age of selfish activity and profusion. The means of enriching himself, at least

of extricating himself from want, were often placed in his power, and he as often rejected them. Alcibiades offered him land on which he might build a house, but he refused it pointedly, observing, "Had I wanted shoes, would you have offered me leather to make shoes for myself?—and ridiculous should I have been in taking it." Charmides would have given him slaves, as a source of revenue by their labour. This offer also he refused.⁴ In the same spirit, he would often cast a look at the number of things that were sold, and say to himself, "Of how many things I have no need!"⁵ Thus was his whole plan of life studiously opposed to the acceptance of any provision for his comfort or ease. It was a service of the Deity in which he felt himself engaged, and in the prosecution of that, solemnly devoted to a course of hardy poverty.⁶

In the domestic relations of life, he lived an Athenian among Athenians. He differed from other heads of families at Athens in this respect, that in his dedication of himself to his philosophic mission, he took no thought about the management of his private affairs. His home was abroad; his household the people of Athens. Still he discharged the duties of a husband, and the father of a family; and that under trying circumstances, unless the proverbial severity of temper of his wife Xanthippe be esteemed an idle scandal of the day. No Athenian, indeed, was truly domestic, in the sense of making his home the scene of his highest interest and enjoyment. Nor was Socrates domestic in this sense. Still less was he so than other Athenians; inasmuch as his very profession of life was a call from the bosom of his family. But in the midst of these avocations from his immediate home, and the vexations to which he was subjected there, he was not estranged from the ties of domestic affection. Xenophon has recorded a simple and touching trait of the character of Socrates under this particular point of view—a trait the more interesting, as almost every thing else that we know of the philosopher is drawn from his life in public. It occurs in the course of a conversation between Socrates and his son Lamprocles, who had complained of the insufferable temper of his mother Xanthippe. "What," said he to the youth, "do you think it more annoying to you to hear what she says, than it is to the actors, when in the tragedies they say every thing bad of one another?" "But they, I conceive," replied the son, "bear it easily, because they do not suppose that the speaker, in contradicting them, intends to hurt them, or that, in threatening, he intends to do them any ill." "Then are you," resumed Socrates, "vexed, when you well know that what your mother says to you, she says, not only intending no evil, but even wishing more good to you than to any one else; or do you regard your mother as unkindly affected towards you?" Lamprocles disclaiming this latter supposition; "Do you, then," he added, "say of her, who is both kind to you, and takes every possible care of you when you are sick, that you may recover, and want nothing proper for you, and who, moreover, prays to the gods in your behalf for many a good, and pays vows,—that she is vexatious? For my part, I think, if you cannot bear such a mother, you cannot bear what is good for you."⁷

From the description given by Plato of the family of Socrates in the prison-scene, it would appear, that Socrates had other three children besides Lamprocles,—for Lampro-

¹ Plato, Apolog. 28. c. op. i. p. 67. Diog. Laert. in vit. Ælian, Var. Hist. iii. 17. ² Plato, Conviv. Ælian, Var. Hist. iv. 11.

³ About L. 400 of our money. Plutarch (in his life of Aristides) finds fault with Demetrius Phalereus for having endeavoured to remove the imputation of poverty from Socrates, by stating that Socrates had land of his own and seventy minæ put out to interest by Crito. Demetrius, however, seems only to have stated what he believed to be the truth. The idea of his extreme indigence originated probably with the caricatures of his profession of poverty by the comic poets; and true as it was substantially, was afterwards, it seems, maintained by his friends and admirers, as the evidence of the consistency of his life with his avowed contempt for worldly possessions.

⁴ Diog. Laert. in vit.

⁵ Plato, Apolog. ἄλλ' ἐν πενία μὲν εἶμι διὰ τὴν τοῦ θεοῦ λατρείαν. Op. i. p. 5.

⁶ Ibid.

⁷ Xenoph. Mem. ii. 2.

Socrates. cles died at an early age, before his father,¹—who were yet children, one of them a boy, another a child in the arms, at the time of their father's death.² We learn from other authorities,³ that two of his children were named Sophroniscus and Menexenus; but they are said to have been the children, not of Xanthippe, but of another wife, Myrto, the grand-daughter of Aristides the just.⁴ To account for this, it has been stated, that after their disasters in Sicily, the Athenians made a decree authorizing double marriages, with the view of recruiting their exhausted population. But this statement does not appear to be borne out by the earlier authorities on the subject of Athenian legislation. Nor is it probable that a law should have been enacted, directly sanctioning a form of polygamy. It appears, that during the pressure and confusion of the Peloponnesian war, persons obtained the freedom of the city of Athens, whose title was objectionable on the constitutional ground of their not being born of citizen-parents on both sides. Thus had Pericles, after the death of his two legitimate sons, obtained the admission of his son, Pericles, by Aspasia, to the privilege of citizenship;⁵ though he had himself carried, some time before, a law of strict limitation, under which, nearly four thousand were deprived of the franchise.⁶ Such extension of the privilege to the offspring of illegal unions, possibly gave a pretext to the supposition, that a decree passed at Athens sanctioning bigamy.

Some difficulty, however, arises on the subject of the marriage of Socrates, from the conflict of authorities. Whilst it is asserted on the one hand, that he was married to Myrto and Xanthippe at the same time; on the other hand, others assign them both as his wives, but in succession, and also differ as to the order of succession. But the silence of Plato and Xenophon respecting any other wife of Socrates but Xanthippe, and their coincidence in speaking of her only as the mother of his children, may be regarded as sufficiently decisive of the point against every subsequent authority. Indeed, the reference to Aristotle, given by Laertius, which is the chief ground for believing that Socrates was married also to Myrto, is very questionable. Plutarch doubts whether the treatise to which Laertius appeals for the fact, is the genuine work of Aristotle. From the manner, too, in which the name of Myrto appears to have been introduced in the account, nothing more may have been intended, than that Socrates found her in a state of widowhood and distress from poverty, and took care of her at his own home.⁷ Aristides belonged to the same tribe and the same demus or borough, as Socrates; and a reverence for the virtues of the grandfather, may have combined with these almost domestic ties, to call forth such an act of friendliness to the disconsolate Myrto. And, if this be the case, as is probable, it would only add an interesting instance of that liberal benevolence which characterized the whole conduct of Socrates.⁸

It is a confirmation of this conclusion, that all the anecdotes of the private life of Socrates, with one exception, and that evidently a fabricated instance,⁹ bring Xanthippe on the scene. On his inviting some wealthy persons to supper, it is Xanthippe who is distressed by their deficient means of hospitality, and to whom he replies, "Take courage; if they are worthy people, they will be satisfied; if they are worth-

less, we shall care nothing about them."¹⁰ It is Xanthippe whom he reproves for her particularity about her dress on the occasion of some public spectacle, as more desirous of "being seen than to see."¹¹ It is of her again that Alcibiades expressed his wonder how he could bear with her, when he simply, but pointedly referred him to her just claims on his affection as the mother of his children.¹² On another occasion, his disciple, Antisthenes, is said to have asked him, with reference to Xanthippe, why he did not study to improve the disposition of his wife, whose violence of temper (he observed) was unexampled in the history of domestic life. Instead of confirming the censorious remark, he turned it, according to his usual method, to a practical illustration of his philosophy. "If Xanthippe was hard to be controlled," was the tenour of his answer, "it was only a proper discipline to him for the management of men; as those who would be masters in horsemanship, began with managing the most spirited horse, after which, every other would be tractable."¹³ These stories, and the like, handed down or invented by the humour of the times, may be merely exaggerations of the fact of the inconvenience and dissatisfaction occasionally felt at the philosopher's home, by his habitual neglect of his domestic concerns, and the duty of exertion consequently imposed on Xanthippe beyond Athenian women in general. She appears indeed to have tenderly loved her husband, if Plato has faithfully traced the picture of her visit to his prison, and her extreme anguish at that trying hour. And he also knew her value, if his affection may be judged of, as surely it may, by the kind and gentle considerateness of his manner in committing her to the care of his friends at parting, and his absolute reserve of his feelings on that occasion.¹⁴ The picture indeed is drawn by the hand of a consummate master; and Plato, it is true, was not present on the occasion. But we must believe, that in painting a scene that must have been impressed on the mind of the disciples of the philosopher, above every other incident of his life, and of which persons then living must have retained a lively recollection, he took his outlines at least of these interesting particulars from the real state of the case.

But the allusion to these circumstances brings us prematurely to the solemn tragedy which closed his intrepid and energetic career. We have yet to contemplate him pursuing for many a year his unwearied labour of awakening his countrymen from their dreams of knowledge and happiness to the realities of their condition in the world. Great indeed must have been the address, which could recommend the severe and wholesome truths inculcated by him, to the hearing of the vain and volatile Athenians. To none is the practical application of a principle, so condemnatory of human folly and impertinence, as the maxim, "know thyself," truly welcome. And yet this was the burthen of the teaching of Socrates for a series of years, among a people, whom it was far easier to please by praising to excess, than not to displease by censuring ever so slightly. They would listen, indeed, patiently to general invectives on their public conduct, conveyed in the impassioned eloquence of their orators; as persons will even now sympathize with general descriptions of the depravity of human nature, or of whole classes of men. But all refuse the pain of direct self-appli-

¹ Plutarch, De Gen. Socr. p. 331.

² Aristotle, cited by Laertius in vit. Socr.

³ The same who was among the generals at the battle of Arginusæ, and who were cruelly and iniquitously sacrificed to party spirit after their great victory.

⁴ Plutarch in Pericl. Op. i. p. 667.

⁵ The poverty of the family of Aristides appears from Ælian, Var. Hist. x. 15.

⁶ Plutarch in Aristides, Op. ii. p. 542. Plutarch adds, that Panætius had sufficiently refuted the story of the double marriage in his observations on Socrates. The story is also questioned by Athenæus. Deipnosoph. xiii. 2.

⁷ Porphyry in Theodorit. Therapeut. xii. tells of altercations, even to blows, between Xanthippe and Myrto, whilst Socrates stands by and laughs, amidst their joint attacks on himself.

⁸ Diog. Laert. in vit.

⁹ Ælian, Var. Hist. vii. 10.

¹⁰ Diog. Laert. in Vit.

¹¹ Xenoph. Conviv. ii.

¹² Plato, Phædo, p. 135.

¹³ Plato, Phædo, pp. 135, 262.

¹⁴ Diog. Laert. in vit.

Socrates. cation of the truth; and Athenians, especially, regarded with invidiousness every attempt to impart to them moral instruction. Every Athenian, they thought, was capable of communicating this kind of knowledge, at least every educated Athenian, every individual of the higher order of citizens.¹ They wanted no one to teach them virtue. Hence the allusion made on so many occasions by Socrates to the question, whether virtue could be taught or not. It was, indeed, part of the profession of the Sophists to teach virtue;² but it was as an accomplishment or art, and not as a *discipline of life*, that it entered into the system of the Sophists. Socrates uprooted this vain notion. He laboured to impress on the Athenians, that so far from their being able to teach virtue, there were none who knew what virtue was. They had yet to learn *themselves* in order to that purpose. This, then, was his great difficulty. It was not the difficulty of communicating *new* knowledge, but that of leading men to unlearn their presumptions and conceits, and to *feel the necessity* of moral instruction.³ That he should have succeeded then in any degree in such an attempt,—that he should have been able to carry on the effort for so many years, in the very centre of Greek civilization,—that, proceeding on so broad and fundamental a principle of reformation, presenting no definite system on which a sect might fasten, no specific lure to the zeal of party, he should have drawn around him so many followers and admirers,—this is the extraordinary effect in the case of Socrates, which shows the powerful charm of his address. To persons offering any particular instruction, or professing to qualify them for the office of statesmen and orators, the Athenians were most ready to attend; and many doubtless did attend to the conversations of Socrates with this view. They could not but admire the skill which he displayed in arguing with every one that came in his way; not with the vulgar only, but with those who had the highest reputation for talent in reasoning, and for the extent of their knowledge. They saw his superiority to the Sophists, on the very ground on which the Sophists set up their pretensions. Many, accordingly, flocked to him as the best master in political science and dialectical skill, particularly as he was always accessible, and his instructions were perfectly gratuitous. Some, too, of a better nature than the rest, were won by the honest and manly purpose which shone through his teaching and manner on all occasions; whatever disguise of irony, or humour, or sophistry, he might assume. There were even some of the young men, whose habits of life were reprov'd, and principles condemned, by his searching interrogatories, but who yet were won to attention by the charm of his instruction, and patiently heard from him truths which they would not have listened to from any other lips. For who else could stay, even for a moment, the wild impetuosity of Alcibiades, or

the ferocious arrogance of Critias? Their motives in resorting to Socrates were chiefly selfish and political. It was in pursuit of their schemes of ambition that they sought his society. Still he was able to retain them for a time at least, though they found his instructions very different from what they calculated on receiving; and so long as they continued to associate with him, they exercised a degree of self-restraint which strikingly contrasted with the habitual profligacy of their lives.⁴ Alcibiades is represented by Plato, as confessing that he, to whom the feeling of shame was scarcely known, yet felt abashed before Socrates; that he was enchanted by him as by the flute of Marsyas, and constrained to acknowledge his own deficiencies and neglect of private duty in the midst of his officious zeal for the public service. And this feeling, Alcibiades says, was general; for that there was no one, woman, or man, or boy, that could hear him, or even his words repeated by the most indifferent speaker, but felt taken by surprise, and riveted in attention.⁵

This attention, too, it should be observed, was excited by the address of Socrates, amidst much in his outward form and mien, that, by exciting ridicule, might have repelled the sentiment of respect. The comparison of him to the satyr Marsyas, with all allowance made for comic exaggeration, was true in more respects than that of the enchantment of his conversation. His countenance, strongly marked by that arch intelligence, which half-concealed, half-betrayed, the earnest deep thought, under the light veil of irony and humour, presented features resembling those of the grotesque images of the Sileni. There were the prominent dilated eyes, scarcely parted by the low ridge of the nose, the broad expanded nostrils, the wide mouth with its thick lips, such as the sculptors delighted to represent in those rude but poetic forms.⁶ Then his manner of looking about him, his head fixed, whilst his eyes traversed the space around, glancing from side to side, excited the smile of wonder in the spectator, as to what this strange solemnity of aspect might portend. Add to this, the clumsy protuberance of his figure, so repugnant to Grecian notions of the symmetry of form, and the awkwardness of his movement⁷ before the eyes of a people who had a lively perception of elegance in every gesture and motion.⁸ These were circumstances which, to the fastidious taste of the Greeks, would appear more important than we, in these times, can well conceive. They judged of intellectual character more from physiognomy⁹ (physiognomy, that is, considered as a science, of mental indications from bodily forms in general) than we are apt to do. Thus in regard to Socrates, the physiognomist, Zopyrus, who, as Cicero informs us,¹⁰ professed to discern the manners and natures of men from their body and features, pronounced that Socrates was stupid and heavy, because the outline of his throat was not con-

Socrates.

¹ Xenoph. Mem. iv. 2. 24. Κατέμαθες οὖν πρὸς τῷ ναυῷ που γεγραμμένον τὸ Γνᾶθι σαυτὸν; "Εγωγε. Πότερον οὖν οὐδέν σοι τοῦ γραμματός ἐμέλησεν, ἢ προσέσχεες τε καὶ ἐπεχείρησας σαυτὸν ἐπισκοπεῖν ὅστις εἴης; Μα Δί, οὐ δῆτα ἔφη. καὶ γὰρ δὴ πάνυ τοῦτο γε ὦμην εἰδέναι· σχολῇ γὰρ ἂν ἄλλο τι ἦδειν, εἴγε μὴδ' ἐμαυτὸν ἐγίγνωσκον, κ.τ.λ.

² Isocrates speaks of them as σύμπασαν ἀρετὴν καὶ εὐδαιμονίαν παλωῦντες, and, again, as τὴν εὐδαιμονίαν παραδιδόντας Or. c. Soph. 3. 4.

³ Plato, Euthyphro, 3. c. Ἀθηναίσις γὰρ τοι, ὡς ἐμοὶ δοκεῖ, οὐ σφόδρα μέλει, ἂν τινα δεινὸν οἴωνται εἶναι, μὴ μέντοι διδασκαλικὸν τῆς αὐτοῦ σοφίας· ὃν δ' ἂν καὶ ἄλλους οἴωνται ποιεῖν τοιοῦτους, θυμοῦνται· εἴτ' οὖν φθόνῳ, ὡς σὺ λέγεις, εἴτε δι' ἄλλό τι. Op. 1. 6.

See the same indicated at the opening of the Protagoras, where Socrates ironically throws out his opinion, that virtue cannot be taught; founding it on the fact of the indiscriminate admission of all persons to advise on political affairs in the Assembly, whilst on particular subjects, as in a question of building, those only were consulted who were proficient in the art. 'Επειδὴν δέ τι περὶ τῆς πόλεως διοικήσεως δέη βουλευσασθαι, συμβουλευεῖ αὐτοῖς ἀνιστάμενος περὶ τούτων ὁμοίως μὲν τέκτων, ὁμοίως δέ χαλκεύς, σκυτοτομος, ἔμπορος, ναύκληρος, πλούσιος, πείνης, γενναῖος, ἀγεννής. Plato, Op. iii. p. 105; also Meno. Op. iv p. 375.

⁴ Xenoph. Mem. i. 2. 24.

⁶ Xenoph. Conviv. v. Plato, Theætet. 143 e.

⁷ The idea of his attempting to dance excites a laugh in the guests in Xenophon's Banquet. Xenoph. Sympos. He says there that he practised dancing for the sake of exercise.

⁸ Xenoph. Conviv. ii. 19.

⁹ Aristotle introduces in his Analytics (Anal. Prior. ii. c. ult.) a notice of the subject, as affording matter of consideration to the dialectician.

¹⁰ Cicero, De Fato, c. 5.

Socrates. cave, but full and obtuse. Prejudices accordingly drawn from the personal appearance of Socrates may reasonably be believed to have tended to render his teaching unwelcome in its first impressions. But soon this fastidiousness would give way as he proceeded; and those who began to listen with a smile at the uncouthness of his form, and the quaintness of his manner, would be attracted to admiration of the intelligent and kindly expression which lighted up those rude features, and would find themselves lingering in his presence in spite of themselves.

The story of Euthydemus "the handsome," as he was called, may be taken as a specimen of such an effect. Euthydemus, proud of his personal accomplishments, and not wishing to be thought indebted to any one for his learning and eloquence, had studiously avoided the society of Socrates. Socrates, however, with his usual dexterity, contrives to excite his attention, and gradually interests him in conversation. Euthydemus shrinks back at first on his self-conceit, but at length is so won upon by the persuasive reason of the philosopher, as freely to acknowledge his own ignorance and need of instruction; and, ever afterwards, he is found by the side of Socrates, his devoted admirer and follower.¹

Some, indeed, took offence at the plain truths which Socrates brought home to them, and no longer frequented his society.² But these were the inferior sluggish minds, which no arts of address could rouse to a sense of their intellectual poverty. Generous, susceptible minds overcame their first reluctance, and yielded themselves fully to his guidance. The faithful attachment of many was evidenced, to the last moment of the philosopher's life. He might have commanded the use of Crito's wealth, had he desired it. Such, indeed, was the confidence which Crito reposed in his sincerity of purpose, and so highly did he value his instructions, that to no other would he commit the education of his sons, but made them fellow disciples with himself of his own revered master and friend. And this friendship was warmly requitted by Socrates. For it was by his counsel that Crito was saved from the malicious arts of the sycophants. These pests of Athenian society were not to be encountered by the simple testimony of a life contradicting their mercenary calumnies; and Crito was one of those who would rather pay their money, and compromise the attack, than take the trouble of defending themselves. They were only to be foiled by turning their own weapons against themselves. By the suggestion of Socrates, accordingly, Crito enlisted in his service a clever individual of this class, Archdemus, who effectually checked the iniquities of which his patron was the object, by counter-prosecutions of the sycophants, and exposure of their conduct; acting as a watch-dog, according to Xenophon's description, against those rapacious wolves.³

The devotedness of Plato and Xenophon to their master, speaks from every line of their writings. These writings are, in fact, as much monuments of the influence of Socrates over their minds, as of their own genius. And what human teacher has ever had such glorious trophies erected of the conquests of his philosophy as the extant works of these master minds? Entirely different as they are in character,—the one flowing with the full stream of impassioned feeling, and lively elegant imagination, and the abundant treasures of literary and traditionary wisdom,—the other sensible and acute and practical, forcible by his very simplicity and the terseness of his unaffected eloquence,—they bear distinct yet conspiring evidence of the ascendancy of that mind which could impart its own tone and character to such disciples. Both of them, indeed, lead us to think that they felt his society as a kind of spell on them. For,

when Plato speaks of the charm of the discourses of the Sophists, he seems to speak in irony of them what he thought in truth of Socrates himself. So too, when Xenophon introduces Socrates describing himself as skilled in "philters and incantations," he is evidently presenting that idea which the conversations of Socrates impressed on his own mind. He seems almost to confess this of himself when he informs us, how Socrates triumphantly appealed to the marked devotedness of his followers, in saying, "Why think you that this Apollodorus and Antisthenes never quit me? Why too, that Cebes and Simmias come here from Thebes? Be assured, that this is not without many philters, and incantations, and spells."⁴

To the same honourable band of attached disciples might be added many other names afterwards renowned in the annals of Grecian history and literature. Isocrates, Aristippus, Antisthenes, each of whom became afterwards masters themselves, were content to follow in his train. Antisthenes especially, who, by perverting the Socratic simplicity of life into a profession of austerity, became the founder of the Cynic school, was never from his side. He would walk from the Piræus to Athens, a distance of about four miles, every day, in order to be with Socrates. And whilst Cebes and Simmias came from Thebes, Euclid, the founder of the Megaric sect, was not deterred by the bitter hostility between Athens and his own city of Megara, from seeking the society of Socrates at the hazard of his life. Even during the war, when the Megareans were excluded by a rigid decree, he continued his visits to Athens, adopting, it is said, the disguise of female attire, and so passing unobserved into the city at nightfall, and returning at day-break.⁵ The same individual gave still more conclusive evidence of his zealous attachment to Socrates afterwards; when he opened his house and his heart to receive, at Megara, his brother disciples, in their panic on the death of their master. So strong was the tie of reverence and affection which subsisted between the philosopher and those whom he drew around him. They formed, indeed, a sort of select family, each of whom was engaged in the pursuit of his own peculiar employments and tastes in the world, whilst all looked up to Socrates as their father and head, and ever recurred to his society as to their common home.

This domestic intercourse subsisted in the midst of a city harassed with jealousies and dissensions, and with severe afflictions of war and pestilence. Socrates remained unmoved through all these convulsions of the city, preserving a constant evenness of temper, so that Xanthippe could testify of him, that she never saw him returning at evening with a countenance changed from that with which he left home in the morning.⁶ Nor could even the merriment of which he was sometimes the object, discompose his settled gravity and good humour. On one occasion, returning from supper late in the evening, he was assaulted by a riotous party of young men, personating the Furies, in masks, and with lighted torches.⁷ The philosopher, however, without being irritated by the interruption, suffered them to indulge their mirth; only he required them to pay that tribute which he exacted from every one that came in his way, to stop and answer his questions, as if he had met them in the Lyceum, or any other accustomed place of his daily conversations. Himself sound in mind and body, (for his habitual temperance saved him from the infection of the plague which so obstinately ravaged Athens,) he was enabled to give advice and assistance to all of his country in the midst of the physical and moral desolation, in which every one else seems, more or less, to have participated.

Thus were the years of a long life quietly and usefully spent; and he had nearly reached that limit at which

¹ Xenoph. Mem. iv. 2.

² Aul. Gell. vi. 19.

³ Ibid. 40.

⁴ Ælian, Var. Hist. ix. 7.

⁵ Ibid. ii. 9.

⁶ Ibid. iii. 2.

⁷ Ibid. c. 29.

Socrates. nature herself would have gently closed the scene of his philanthropic exertions, when the hand of human violence interposed to hasten the approaching end.

The annals of party spirit at Athens had already recorded many a deed of dark and wanton cruelty. But they were yet to be stained with the iniquity of a persecution even to death, of him, who had been the greatest benefactor and ornament, not only of Athens, but of the whole community of the Grecian name.

The banishment by ostracism had this redeeming merit, that it was an avowal in the face of Greece, of the envious and factious spirit, which drove from the state the individual whose talents or virtues too greatly distinguished him from among his fellow-citizens. The enmity to which Socrates fell a sacrifice, exhibits a deeper character of malignity; inasmuch as it masked itself under a hypocritical zeal for religion and virtue, and thus courted public sympathy for proceedings, against which every voice in Athens and in all Greece should have indignantly protested. Ostracism, again, was content to remove the obnoxious great man from the eyes of his fellow-citizens. The attack on Socrates was satisfied with nothing short of the destruction of its victim.

It was in the midst of the tranquil, but busy course of his daily engagement, that Socrates was suddenly arrested, and without, it seems, any previous intimation of the intended attack, summoned to the portico of the king-Archon, to answer a charge of impiety.¹

The accusation was in this form: "Socrates is guilty of the crime of not acknowledging the gods whom the state acknowledges, but introducing other new divinities: he is guilty also of the crime of corrupting the young." The penalty proposed was death. It has been commonly supposed that the charge was laid before the court of Areopagus. But it would appear rather, from the course of the trial, to have been before one of the popular courts, and probably, from the great number of dicasts or jurors who voted on the cause, before the principal court, the Heliaea.

The circumstances connected with the accusation remain, after the utmost inquiry now possible, involved in considerable mystery. We are told that Melitus was the accuser, and that he was supported in the prosecution by Anytus and Lycon. These three individuals are also said to have represented distinct classes of persons interested in the proceedings; Melitus, who was himself a poet, appearing in behalf of the offended poets; Anytus, a wealthy tradesman and demagogue, resenting the affronts of his brother-tradesmen; Lycon, an orator, or politician by profession, standing up as the assertor of the pretensions of his factious order. But these particulars, though they may account to us in a great measure for the success of the prosecution, do not exhibit the secret agency by which it was effected. The accusers themselves were men of no note or importance in the state. Melitus was a young man; a vain and weak person, it seems, of whom nothing more is known than that the accusation was made in his name. Nor of Anytus and Lycon have we anything to mark the importance, beyond the fact, that the former was included, together with Alcibiades and Thrasybulus, among the persons exiled by the Thirty, and the notice taken of

him by Plato, where he represents him the inexorable Socrates: foe of every thing in the shape of a philosopher, and as parting from a conversation with Socrates in anger.² Merely personal offence, however, could not have given sufficient pretext or weight to so grave an accusation. Nor can we suppose that it was even the combined interest of the three classes represented by the three accusers—the poets, the tradesmen, and the orators—which carried the condemnation of so respected a person. The ground of the attack must lie deeper; and the men whose names appear so prominently in this fatal conspiracy against the life of the venerable old philosopher, could only have been the puppets moved by some secret and more commanding force. The trial would seem to have been only a solemn pageant, exhibited before the public, as a prelude and justification of a deed of murder already resolved on by its real though invisible perpetrators. Whilst the charges themselves, as set forth by the nominal accusers, were but feebly sustained, it is evident that no defence, however just and able, could have availed to avert the sentence of condemnation. The body of jurors before whom the cause was heard, appear to have been disposed to acquit the accused, if we may judge from the number of votes which were given in his favour; and yet the majority were overruled. This in itself would lead us to think that some secret influence had been exercised, to obviate the chance of failure of the ordinary ostensible means of judicial assault. And so Socrates himself appears to have felt; if Plato and Xenophon have faithfully reported the substance of his reply to the accusation in their Apologies. His defence, as there represented, is that of one who retires, on his own consciousness of right, from a bootless conflict with adversaries who are not to be appeased by argument and persuasion. It does not set forth the strength of his cause as against an opponent, but simply asserts the truth and merit of the course of life which he had been pursuing.³ The sentence accordingly excites no surprise in him. He yields himself up as to the sweeping of a tempest, with which it is vain to parley. Would we then explore the circumstances of the trial and condemnation of Socrates, we must obtain a deeper insight into the moving power of Grecian politics,—the spirit of the heathen religion, and the mode of its action on the conduct of states and individuals. This appears to be the proper solution of the case of Socrates. The circumstances of the case evidently point to this. And though, from the want of information, we cannot very distinctly trace the working of the religion of the times in the particular instance before us, we may, from a closer consideration of the facts, not unreasonably suspect its active operation and instrumentality.

Speculators have sometimes spoken of the mild and tolerant spirit of paganism. The observation, however, is superficial and untrue. The facility with which the polytheistic worshipper transferred his offerings and prayers to every new idol, has been mistaken for a readiness to admit any variation from the established worship, or any freedom of opinion respecting divine things, without offence. The contrary is the fact. The heathen, resting his religion on ancient tradition⁴ and the authority of the priests, and not on any intrinsic evidences of its truth, could not but feel a jealousy of any departure from what he had thus received,

¹ Plato, Thætet. ad fin. Euthyphro. et alib. The king-Archon was a sort of minister of state for the department of religion—the representative, under the democracy, of the priestly office of the king during the monarchy at Athens. See Demosthenes, c. Neæra. p. 1370, ed. Reiske.

² Xen. Hell. ii. 3. 42, 44.—Plato, Meno.

³ See the same exemplified in what Socrates is made to reply to Callicles in the Gorgias of Plato, p. 162, τοσούτον μέντοι καὶ ἐγὼ οἶδα, ὅτι παθος παθοίμι ἂν εἰσελθὼν εἰς δικαστήριον, κ.τ.λ.

⁴ Demosthenes, in his Oration against Neæra, p. 1370, speaks of a column erected in the temple at Limnæ, ἐν τῷ ἀρχαιοτάτῳ, ἱερῷ τοῦ Διονύσου καὶ ἀγιοτάτῳ, and standing in his time, which stated, among other things, ἵνα κατὰ τὰ πάτρια θύηται τὰ ἀρρήτα ἱερὰ ὑπὲρ τῆς πολέως, καὶ τὰ νομισμένα γίγνηται τοῖς θεοῖς εὐσεβῶς, καὶ μηδὲν καταλύηται, μηδὲ καινοτομήται: and he sums up the account with εἰδῆτε, ὡς σεμνὰ καὶ ἅγια, καὶ ἀρχαῖα τὰ νομιμὰ ἔστιν.

Socrates. or any attempt to bring the subject into discussion. It was not only the primitive Christians that were stigmatized by heathens as atheists, because they renounced the divinities of the heathen creed, but the same reproach was long before cast upon those among the heathens themselves, who, with however pious disposition, ventured to speculate on religion. A traditionary religion will tolerate any laxity of thought or conduct which professedly admits its authority, whilst it peremptorily puts down every thing which impugns the principle of absolute deference to its authority. Thus we shall find, that, where that principle is carried to the utmost, there co-exists with it a scarcely concealed infidelity, and an unrestrained licentiousness of conduct; and, at the same time, also an extreme sensitiveness in regard to deviation from the orthodox profession and language. We have unhappily seen this in those Christian countries, where the true faith, the principle of devout submission to the word of God, has been transformed and perverted into a doctrine of implicit deference to the authority of the ministers themselves of that word. There,—as, for example, in Spain and Italy,—where the authority of the church is bowed to most submissively, practical infidelity and immorality shew their front with impunity, whilst the expression of opinion or argument on questions of theology is discouraged and silenced, if no longer now, as once, crushed at its outbreak by the dark terrors of an Inquisition. The same fact was intensely exemplified in heathen Athens. At no place was piety, as piety was understood by heathens, more in honour. No state boasted such a tradition of sacred associations as Athens. In none were there so many festivals and solemnities of religious observance, as in Athens.¹ In none did the priests of religion hold such sway. Witness their power over Alcibiades, at the moment of his political triumph, and amidst the caresses and admiration of his fellow-citizens, when he felt himself obliged to relinquish his command in Sicily, and desert his country, rather than encounter at home the threatened prosecution for his profanation of sacred things. Witness their power again in the instance of the same Alcibiades, at his restoration to the command of the army, when, to conciliate their favour, he delays the urgent expedition, and keeps the soldiers under arms along the road by which the sacred procession passed from Athens to Eleusis. Witness further, the frequent prosecutions at Athens on charges of impiety of which we read, and of which we have monuments in extant orations. But, amidst this strictness of external profession, in no place was there a more entire license as to practical irreligion. Their festivals abounded with rude and obscene mirth. Their drama, whilst it inculcated in direct precept the belief and worship of the gods, indulged in the most profane ribaldry and ludicrous representation of sacred things. Yet were these follies and excesses tolerated, because under them a regard was still maintained to the authority which upheld the religion, as in the “mysteries” and “moralities” enacted with the connivance of the papal power in modern times; and the people at large were satisfied with a religious system, which was exhibited to them as so good-humoured and humane. They were tolerated, indeed, but not without the like injury to the religious feelings, as in the parallel

cases, where a corrupted secular Christianity has ventured on the like palliations of its despotism. For all the while the people were losing their hold of the popular religion. Those who thought at all on the subject, either rejected it altogether, or accounted it a mere matter of opinion and external ordinance; whilst those, on the other hand, who were content to receive every thing traditionary as divine on the mere principle of deference to the priests, readily engrafted every new superstition on the received religion. Thus, whilst infidelity and superstition grew up at Athens, and flourished together, and often perhaps in the same mind, the connexion between religion and morality was altogether lost sight of and dissolved. Men began to regard themselves as devout, and friends of the gods, whilst they were committing deeds of violence and lust, and blindly and wickedly endeavoured to support the cause of religion by forcible suppression of the truth, and persecution of those who subjected their tenets or their rites to the test of inquiry. Thus, whilst Aristophanes was amusing the people, not of Athens only, but from all parts of Greece, at the public festivals, with ludicrous representations of the popular theology, and loosening more and more any existing associations of reverence towards the objects of their worship, severe prosecutions were carried on from time to time against all who in any way made religion a matter of debate, or seriously brought it into question with the people. The same persons can take part in the vulgar low jest, and shew their real contempt of religion by their carelessness about oaths and the practical duties of religion, and yet join zealously in the prosecution of offenders against established notions of religion. It is the same habit of mind in both cases; a habit of looking at religion as a general rule of orthodox profession,—as a rule binding on a community, and a test of its soundness of doctrine,—rather than as a personal concern, and a trial of the spirit of a man. “He has brought Gentiles into the temple, he has abolished circumcision, he has profaned our religion,” was the outcry against St. Paul; and yet these same persons thus clamorous against the apostle, were minding earthly things all the while, sticklers for externals, yet idolaters in their personal religion, as men of covetousness, and slaves to the appetites of the body.

At Athens, accordingly, though there was no freedom of religious opinion, the religion might be employed to excite festive mirth, and gratify the levity and licentiousness of a dissolute yet intellectual populace, amidst the charms of poetry and music and the solemn graceful dance. For then the associations of deference to the mysterious agency which held together the traditions of the popular creed were not violently broken asunder. There still remained in the minds of the people an awe at the indefinite mystic truth, hidden under the embroidered veil held before their eyes. They knew that the splendid drama of religion, which at once gratified their refined intellectual taste and their sensibility, was not the whole of their religion. They had also the Eleusinian mysteries; rites of religion performed in secrecy, and fenced round with the terror of death to him that should divulge them; delegated to a few, the initiated only, and incommunicable to the vulgar; of which the popular rites were but the rude symbols.² The popular wor-

¹ Aristoph. Nub. 298. οὐ σέβας ἀρρήτων ἱερῶν, ἵνα
μυστοδόκος δόμος
ἐν τελεταῖς ἀγίαις ἀναδείκνυται,
εὐρανοῖς τε θεοῖς δωρήματα,
ναοὶ δ' ὑψιφρεφεῖς καὶ ἀγάλματα,
εὐστέφανοί τε θεῶν θυσίαι θαλίαι τε
παντοδαπαῖς ἐν ὥραις, κ.τ.λ.

Also Thucyd. ii. 38; and De Repub. Athen. attributed to Xenophon.

² Isocrat. Panegy. p. 54. “Ὅς οὐχ οἶόντ' ἄλλοις ἢ τοῖς μεμνημένοις ἀκούειν . . . καὶ τὴν τελετὴν, ἥς οἱ μετέχοντες περὶ τε τῆς τοῦ βίου τελευτῆς, καὶ τοῦ σύμπαντος αἰῶνος, ἡδίστους τὰς ἐλπίδας ἔχουσιν.”

Socrates. ship might wear the form of caricature, the grotesque, the farcical, and even the profane, as being merely the pantomime in which some recondite interior religion was dimly and wildly shadowed. The people laughed at what they saw and heard at their festivals. But amidst their laugh there was evidently a feeling of awe, which subdued the luxury of their mirth; a consciousness that, whilst they sportively shook the chain of their superstition, its iron entered into their soul. We see, on the other hand, Aspasia, the favourite of Pericles, at the time of the greatest popularity of that most popular leader, summoned before the courts, to answer a charge of impiety, and scarcely defended by the eloquence and the tears of Pericles himself, from the inexorable power, whose vengeance she had provoked by her philosophical speculations. Protagoras, admired as he was and courted at Athens for his talents in his profession of a Sophist, was expelled from the city and borders of Attica by the Athenians, and his books were collected by proclamation and burnt in their agora, for his avowed scepticism as to the existence of the gods.¹ Æschylus, whose very poetry is instinctive with religion, was accused before the Areopagus of divulging the mysteries in one of his tragedies.² The philosopher Anaxagoras, like Galileo under his papal inquisitors, suffered imprisonment at the hands of Athenian persecutors, for having asserted the material nature of the heavenly bodies, and only escaped death by the intervention of Pericles, and by exile from his adopted home. The extent again, to which prosecutions for offences against the popular religion could be carried at Athens, is shewn in the number of persons who were imprisoned on suspicion of being implicated in the impieties charged on Alcibiades, and the execution of so many, on that occasion of panic, on the unsupported evidence of secret informers. Lastly, not many years before the accusation of Socrates, Diagoras the Melian, and Theodorus of Cyrene, were branded with the epithets of atheists; and the former was forced to fly from Athens on a charge of profanation of the rites, with the price of a talent set on his head for any one who should kill him. And long after the time of Socrates, the same spirit subsisted to drive Aristotle from the Lyceum, and later still, to intimidate the speculations of Epicurus. So strictly was the *authority* of the established worship guarded by a jealous and watchful inquisitorial power, in a state which boasted of its perfect liberty of speech, its *παρρησία*, above all others.

In fact, there was no liberty of speech on this subject in Greece. Every thing relating to religion was to be received as handed down from former ages; as the wisdom of an immemorial antiquity, borne along on the lips of the priest and the prophet, or impressed on mystic rituals, the hereditary trust of sacred families, or symbolized in the pomp and pageant of festivals and games, in the graceful majesty of temples, and the solemn shadows of sacred groves. The inward devotion of such a religion naturally took the form of silence, and reserve, and awe. It was concentrated in the simple dread of profanation. The more superstitious indeed a people is, the more necessary is it that the rites of their religion should be strictly shut up from all inquiry, and a feeling of reserve should be inculcated as essential to the religious character. It is the indefiniteness of super-

stition that holds together the system. Let any one part of the vaguely-floating system be touched too palpably, and the whole crumbles. Thus it has been found, that superstition and infidelity have always gone hand in hand. Diagoras was made an atheist from being at first superstitious. The Athenian people, in like manner, from their superstitious character, were peculiarly exposed to a reaction of impiety. And it was but a wise policy, therefore, that the religion of Athens should be jealously guarded with an awe forbidding all inquiry into its truth.

The colloquial and lively spirit of the Athenians mitigated the intensity of this feeling in the minds of the people at large; and the managers of the system were fain to relieve it, by blending recreation, and mirth, and interesting spectacles, with its public celebration. Grecian superstition accordingly, whilst it bore the essential marks of its oriental origin, in the submissiveness exacted of its votaries, and its mystic reserve, assumed also the mask of cheerful expression characteristic of the genius of the people. Still we see that submissiveness and that reserve strongly marked in the stern denial of the right, not only of private judgment on questions of religion, but even of bringing such questions at all into discussion.

Now, though, as we have already observed, we cannot distinctly trace the steps by which this spiritual despotism was brought to bear on Socrates, we cannot doubt that his was a case which must have attracted its notice. During more than forty years, Socrates had been seen at Athens, going about among all classes of the people, exciting among them a spirit of moral inquiry, urging on them the importance and the duty of self-knowledge, of taking no opinion on mere hearsay, or indolent and self-satisfied trust, but of bringing every thing to the test of discussion and learning, of acquainting themselves, as their first step to knowledge, with the depth and extent of their ignorance. Observers saw in this extraordinary teacher, one of their own citizens, educated in their own institutions, familiar with the habits of Athenian life, ever at home among themselves, recommending himself alike to the young and the old, by the honest though quaint dignity of his manner, and the interest and charm of his conversation. He was not, like Anaxagoras, or Protagoras, or Prodicus, a stranger sojourning among them; a philosopher or rhetorician by profession, or one pursuing philosophy as a trade and a source of subsistence, waiting to be resorted to and courted by the affluent and noble, and reserving himself for occasions of display or profit; but he was found, an Athenian among Athenians, in the market place, in the streets, in the work-shops, at the tables of the wealthy, himself seeking out persons to instruct, asking questions of all around him, and engaging them, even in spite of themselves, in conversation with him.³ In other teachers, philosophy had spoken, according to the observation already made, as from an oracular shrine, to those only who came to inquire of it as votaries and disciples. With Socrates, philosophy walked abroad, insinuating itself into the scenes and business of daily life, and drawing forth the secret treasures of men's minds with its own hands. According to that homely but apt illustration of his mode of teaching, which he was so fond of employing, from midwifery,

¹ Diog. Laer. ix. c. 8. Cic. De Nat. Deor. i. 23. See the story of the daughter of Neæra, as told by Demosthenes, in his oration against Neæra, p. 1369. She had been married under the pretence of being an Athenian citizen, to an Athenian who served the office of the king-archon. As the wife of this officer of the state, she was admitted to the rites of religion, and solemnly inducted into the mystic temple of Bacchus at Limnæ. But it was unlawful for any but a true-born citizen to enter into the temple, or to witness the rites; and her husband consequently was tried before the court of Areopagus for the impiety, and only escaped on the plea of his ignorance of the fact, and on the condition of his dismissing her from his house.

² Ælian, Var. Hist. v. 19.

³ Plato, Euthyphro. 3 d. "Εγὼ δὲ φοβοῦμαι, μὴ ὑπὸ φιλανθρωπίας δοκῶ αὐτοῖς ὅ, τι περ ἔχω ἐκκεχυμένως παντὶ ἀνδρὶ λέγειν, οὐ μόνον, ἀνευ μισθοῦ, ἀλλὰ καὶ προστιθεῖς ἂν ἡδεώς εἴπῃς μου ἐθέλοι ἀκούειν. Op. t. i. p. 6. Xenoph. Mem. i. 2. 'Αλλὰ τῶνδ' ἐτοίμα ἀπέχεσθαι, ἔφη, δεήσει, ὦ Σώκρατες, τῶν σκυτέων καὶ τῶν τεκτόνων καὶ τῶν χαλκῶν, καὶ γὰρ εἶμαι (Critias is speaking) αὐτοὺς ἢ οὐ κατατετρίφθαι διαθρυλλομένους ὑπὸ σοῦ. P. 21.

Socrates. his method freely offered its services in assisting at the birth of the thought with which the pregnant mind was labouring. He busied himself, he used to say, with the officiousness of his maternal art, in exploring the genuineness of the fruit of the intellectual womb, which his dexterous questions had brought to light.¹ Such a person then could not but fix on himself the eyes of every attentive observer of the state of society in Athens. Such teaching evidently could not but have a very considerable influence on public opinion. Particularly when he was seen to be acceptable to men of all parties in the state, to the leaders of the aristocratic faction as well as the humblest citizen, it could not but be inferred that his influence was not a transitory one, dependent on the predominance of any party, but that it would reach to the fundamental constitution of the society at large of the city, and be a leaven of fermentation to the whole mass. What, then, it would naturally be asked, must be the effect of such a teacher on existing opinions in religion? He taught, indeed, that men should acquiesce in what was established in religion; that they should inquire no further here than what simply was the law of the state. He treated, too, the popular imagery of religion with respect. For he would often clothe his instructions in the language of the legends and traditions of their mythology. Nor did he attempt to explain them away, though he waived all discussion of them. He was seen, too, on all stated occasions, sacrificing at the altars of the gods, and joining in the rites.² But, it would be asked, if the citizens were taught to examine into received opinions generally, would they abstain from carrying this principle into the subject of religion? Would they continue still blindly and submissively to follow the voice of authority? Would they not rather, so far as they were disciples of Socrates, begin to speculate on divine things, abandoning that reverence which they had hitherto maintained for the objects of public worship, disputing and discussing without reserve, and exposing to the vulgar gaze what had been all along venerated in mystic silence, and under the veil of symbol? The mercurial temperament of the Athenian was just the soil in which the seeds now scattered by the hand of Socrates might be expected to vegetate. The excessive prosperity, too, of Athens, during the fifty years immediately following the Persian war, and then its condition of struggle against internal faction and the confederate arms of Peloponnesus, were circumstances calculated to foster the profane irreligious spirit in a light-hearted people. Then, instances were not wanting of young men, the intimates of Socrates, and whose minds had been especially cultivated by conversation with him, who proved in the end traitors to the religion, as well as to the civil liberties of their country. Critias,³ afterwards one of the thirty tyrants, and Alcibiades, at once the pride and the pest of his fellow-citizens, whom they loved and hated, and banished and longed for by turns, were striking evidences to the superficial observation of the evil apprehended from the teaching of Socrates. For here were young men of genius, susceptible by nature of the fullest influence of the lessons of the philosopher. And yet these had failed under his hands. What, therefore, might not be expected of minds of inferior order? How would not the religion and the institutions of the city fall into profane neglect and contempt, should the Socratic spirit of inquiry be

imbibed by the next generation of citizens? The observation, indeed, was only a very superficial one, which would infer from such instances the evil of the teaching which these individuals misapplied. Still it is plain, that such cases were pointed at with invidious reference to Socrates and philosophy in general. We find the orator Æschines attributing the death of Socrates to the circumstance of his having educated Critias;⁴ not that he must be supposed to have believed this to have been the whole account of the trial and condemnation of Socrates; but as an orator, he states for the purposes of his argument, what he conceives would be readily believed as part of the account of that event. Plato also studiously addresses himself to the defence of philosophy, from objection on this ground, with evident allusion to Alcibiades and the like cases; arguing that the same individuals who were most susceptible of the good of philosophy, were also such as would be the most apt to abuse it. And probably he had the same design, and refers to the degenerate sons of Pericles himself, as an instance in point to those who cherished the memory of that great man, and of the times in which he flourished, to show that the philosopher was not to be held responsible for the extravagances and vices of the disciple.⁵

The exhibition of the comedy of "The Clouds," appears to have been designed to bring before the people the supposed evil tendency of the teaching of Socrates, as exemplified in such distinguished instances. It was produced in the year B.C. 423, when the philosopher had attained his forty-seventh year, and was at the height of his reputation throughout Greece, and about twenty-three years before his death. There we have Socrates introduced by name under broad caricature, as the representative of the class of sophists, and a consummate master of the arrogant pretension, and sordid cunning, and impiety of the class. The clouds are his only divinities. A profligate spendthrift youth, and a dotard father, are his dupes. The inquisitive method which Socrates practised, is also held up to ridicule and contempt, by identifying it with the frivolous questionings of the grammarians, and dialecticians, and rhetoricians of the day, and with the perverse sophistry which held truth a matter of indifference, or, which amounted to the same thing, called every man's opinion truth, and boasted of its skill to make the worse appear the better cause. It was but too evident to Athenian spectators at least, that the Socrates of Aristophanes was not the Socrates whom they had been accustomed to see and converse with in real life. And the play accordingly failed at the first exhibition. Not all its charms of poetry, and humour, and skilful composition, could obtain for it a favourable reception. Though Aristophanes was aware that the portrait which he had drawn, was not a portrait of the individual, but of the class, there can be little doubt, that he calculated on the sympathy of the people, in giving the name of Socrates to his personification of the sophistical spirit; and that he felt it necessary to depreciate the influence of Socrates as the commanding influence of the day, by attributing to his method all the vices of the schools of the sophists. Socrates is honoured and complimented in the very attempt to weaken the respect for his instructions, and to awaken a clamour against him. The failure of "The Clouds," at the first representation, and one account adds, even at the second, (for the play is said to have been retouched for the third time), has

¹ See especially Plato's *Theætetus* in illustration of this.

² Critias is placed by Sextus Empiricus among the atheists. He is said to have resolved all religion into the enactments of legislators providing against the secret commission of crimes, by inculcating the all-seeing power of the gods. He gives also several lines from a poem of Critias to this effect. *Adv. Math. lib. viii. p. 318.*

³ Æschin. *con. Timarch.*

⁴ See the *Protagoras* and *Repub. vi.*—Xenophon adverts in like manner to the charge of corruption as supported by the instances of Critias and Alcibiades. *Memor. i. 2.* See also the conversation which Xenophon reports between Socrates and Hippias. *Isocrates, in Busir. p. 222, c.* with the like feeling, *denies* that Alcibiades was educated by Socrates; meaning, it seems, that Alcibiades was too short a time with Socrates to be benefited by the instructions of the philosopher.

Socrates.

been attributed to the influence of Alcibiades. Alcibiades indeed has been supposed by some commentators to have been no less the object of attack in the play than Socrates himself, and to have been designated under the name of Phidippides, the youthful and accomplished victim of the sophist. There are certainly some traits in the character of Phidippides, which would seem to point at Alcibiades, whom perhaps the poet, bold as he was, could hardly venture to bring on the stage by name or closer description at this particular time. And we may perhaps justly allow some weight to party influence in neutralizing the effect of "The Clouds" at its first exhibition. Still, when we observe in other instances the great power which the comic muse could wield against a political opponent, as in the attack on Cleon in "The Knights," we cannot but think that there was some strong countervailing feeling in the estimation of Socrates himself. If the account of Ælian be true, Socrates could join in the laugh raised against him; for he was present in the theatre during the acting of the play, and finding that he was the object of attraction, placed himself where all could command a view of him.¹ He knew, and every one in Athens knew, that he was a very different person from the sophists with whom the play identified him. They indeed were corrupters of the young; for they unsettled every established principle in the minds of the young, and gave no substitute for what they profligately swept away. They left the young to be drifted away by the tide of their passions, with no criterion of truth or of right beyond the present opinion or the present interest. But Socrates, whilst he taught the young to inquire into the truth of their opinions, lessened their presumption and self-confidence, by shewing them how apt they were to mistake mere assumptions for knowledge, and to be conceited of their ignorance. His object was truth, and accurate knowledge. He stated difficulties and objections, but not in the spirit of a sceptic, but in order to awaken curiosity, to clear away confusion of thought, and inculcate sound principles of judgment and conduct. He could well then laugh at the jest which glanced from him to its proper objects, the sophists themselves, the very persons against whom his whole teaching was directed. He felt doubtless that he had a hold on the people at large, which the sophists had not. They were for the most part known only to the great and wealthy; those who could receive them into their houses, as they went from city to city through Greece; who sought their society as patrons of literature, or aspirants after political distinction, and who could pay for their instructions.² He on the contrary was accessible to all. He would receive no money from any one. He was the frequent guest of the rich; but he was no less the associate of the artizan and the poor. And too many must have been present in the theatre, when the Socrates of "The Clouds" was amusing the audience by his sleight-of-hand philosophy, who would remember the real Socrates as a man of honesty, and truth, and disinterested benevolence, from whom they had received much useful counsel from time to time, and whom they had ever found affable, and at leisure to enter into their feelings and views with patience and kindness. If we compare the Socrates of the Memorabilia of Xenophon with the Socrates of "The Clouds," we may judge how great was the contrast to those who compared the well-known philosopher of the agora with his portrait as drawn by Aristophanes. If we can smile at the caricature of "The Clouds," and yet love the excellent moralist of the Memorabilia, we may also conceive how harmless the satire of Aristophanes would really be against the object of it; whilst the jokes of the poet, true as to the per-

sonal peculiarities of the philosopher, amused a volatile and clever people. For them to have confounded Socrates with the class of sophists, would have been in them the like palpable mistake, as it would be to confound the philosopher Bacon, on account of some points of resemblance, with the alchemist and empiric of the preceding ages.

It might seem matter of reproach against Aristophanes, that, in selecting the name of Socrates to represent the sophistical spirit which had then so largely corrupted the education and the government of Athens, he pointed the shafts of the comic muse against the very person who was in truth its most successful antagonist. In such a view of the case, however, sufficient justice would not be done to the discernment of the poet. He shrewdly observed in Socrates the master genius which would ultimately cast into the shade all those busy professors of the art of education, who, under the name of sophists, or professors of all knowledge, were then attracting the notice of the world to themselves and their doctrines. Socrates, in himself, Aristophanes could not but admire and recommend to the imitation of his country. He doubtless knew Socrates to be a true patriot no less than himself,—to be steadily aiming to bring back the Athenians to the purity of their institutions, from which they had so sadly degenerated, by his instructive conversations, as he was by the satirical strokes of the drama. Socrates, too, appears to have been his personal friend; for Plato introduces them in his Banquet as meeting on terms of intimacy, about the very time of the exhibition of "The Clouds." But with that freedom which the state of manners, under an absolute democracy, sanctioned and encouraged, Aristophanes did not scruple to bring even the revered name of Socrates on the stage, to give the due point to his satire. He overlooked the individual, the Socrates with whom he familiarly conversed, and presented before the spectators what he saw in Socrates, the living speaking impersonation of the influence of education on the character of a people, for good or for evil. Anaxagoras, or Protagoras, or Prodicus, or any other of the well-known philosophers or sophists of the day, might have occupied the foreground in the comedy of "The Clouds;" had the poet sought to give merely a fugitive sketch of the sophistical spirit of his times, or to single out for ridicule some of its external superficial features. This is what Plato has done on many occasions, and especially in that most animated picture in the dialogue entitled Protagoras, where he groups together the figures of the leading sophists in such admirable relief with each other, and such happy contrast with the unpretending but dignified form of his own loved master and friend. Such a view, however, could not have answered the design of Aristophanes in his play of "The Clouds." His object was to seize the deep, influential characters of the system of education which was then extending itself throughout Greece, and especially as it was manifested at Athens, the great school of all Greece. Naturally, therefore, and wisely, he fixed his eye on an Athenian—and that Athenian, Socrates,—not only as the first Athenian who had appeared in the office of a philosophical instructor, but who, as an Athenian, gave to his lessons the character of Athenian civilization, and fitly exemplified the influence of philosophical education in the hands of an Athenian, and as operating on Athenians.

The poet, indeed, as addressing the eye and the ear of the ordinary observer, and not Athenians only, but strangers of the Grecian name from all parts, mingles with his colouring some playful lights borrowed from the forms of the well-known professional sophists of the day. But neither are these representations, nor the allusions which he

Socrates.

¹ Ælian, Var. Hist.

² Plutarch well characterises the teaching of Socrates, in speaking of him, as ἀνδρὸς ἀτυφία καὶ ἀφελεία μάλιστα δὲ φιλοσοφίαν ἐξανθρωπήσαντος. De Socr. Gen. p. 301.

Socrates. makes to the real eccentricities of manner and uncouthness of person in Socrates, the points on which he desires to fix the attention of the theatre. It is the important modification of the Athenian character, under a system of education which had now reached its maturity. Under the administration of Pericles, that system had already infected the policy of the state, and perverted its courts of justice into sinks of corruption and oppression. Now, at length, it was found domesticated at Athens in the sanctuary of private life. An Athenian had appeared in the character of a professor of philosophy; and around him were gathered citizens of all ranks, from the noble youth who aspired to the helm of the state, and the wealthy patron of literature, to the mean artizan who worked at the forge, and the drudge of the market. What was further to be observed now, was, that the system came recommended by the eloquence of lively and exciting conversation. And how powerful must have been such conversation, as it came forth from the lips of the speaker in the elegant and terse Attic idiom! It was no wonder, therefore, that the comic poet should have seized this moment for portraying the danger which he anticipated to his country from the fashionable education of the day, and thrown all the force of his ridicule on the most attractive form in which it then presented itself, as displayed in the personal teaching and example of Socrates.

The testimony of Plato is to the same effect. Plato has not given us an exact portrait of Socrates any more than Aristophanes has; for he has evidently transferred to the Socrates of his Dialogues, not less of his own cast of mind and manner, than Aristophanes did to the Socrates of his comedy, of the general tone of the sophists. And this is to be accounted for, as in the case of Aristophanes, from the fact, that Plato regarded Socrates as the impersonation of the philosophy of the times. He felt that, to give his own doctrines a proper authority and weight, he could not employ a more effectual organ than the tongue of him who had first given to philosophy an Attic expression, and from whom it would henceforth derive its proper Grecian character.

But though the drama of "The Clouds" was unsuccessful as an attack on Socrates, if it were intended as such, or as an attack on the sophists under the name of Socrates, which is the more probable view of its design, it must not be supposed that the play produced no effect unfavourable to Socrates. The tradition, that Aristophanes was employed by Anytus and Melitus to write down Socrates, does not seem altogether without reason; though it can hardly be literally true, when we look to the distance of time which intervened between the production of the play and the accusation. In the *Apolo-logy* of Plato there is an allusion to the prejudice excited in the young men by the representation given of the philosopher in this play. Nor had "The Clouds" been the only attack on Socrates by Aristophanes; not to mention other comic writers who had made him the object of their humour. In the year 405, not more than five years before the prosecution, the play of "The Frogs" had been exhibited, in which a pointed allusion is made to the influence of Socrates in terms of reprobation.¹ In the mean time, also, the same note had been struck; for the play of "The Birds" was produced in the middle of this

interval between "The Clouds" and "The Frogs," in the year 414; and in that again the Athenians are warned against the corruptions and enchantments of the philosopher.² And it is very possible that many who lived to witness the formal accusation of Socrates, might have received their earliest prejudices against the philosopher by what they heard in the theatre then,—prejudices, too, which the course of events, the miseries of the Peloponnesian war, and the anarchy consequent upon it, may have ripened into exasperation.³ For they saw their country fallen from its proud station in Greece, to the condition of a dependent state; and they were led to ascribe their misfortunes to a change of habits since the days of Marathon and Salamis,—to their having deserted the palæstra and the field, and become, from a body of devoted patriots and soldiers, students of rhetoric and masters in debate.⁴ During all this time Socrates continued the unrivalled teacher of the youth of Athens; increasing, indeed, in renown and popularity; and surrounded by a number of students of philosophy and political science from all parts of Greece. He had, in fact, converted Athens into a university of Greece. For though he had no professed school,—no *φροντιστήριον*, as Aristophanes jocosely represents the scene of Socrates amongst his disciples,—no regular place of meeting, such as Plato had in the Academia, and Aristotle in the Lyceum;—there might be seen around him in familiar conversation, in every part of the city, day after day, the statesmen, and orators, and generals of the republic,—philosophers of established repute from other cities,—the sons of the noblest families of Athens as well as of the humblest citizens,—and the resident foreigners and occasional visitors of the city; some seeking instruction in the art of government, some investigating by his guidance the chief good of man, some studying the theory of eloquence and criticism, some exploring, by the light of his searching questions, the depth of metaphysics, and the subtle speculations of the earlier philosophers; all according to their different pursuits, and in their different degrees, receiving information and general mental culture from the great Athenian sage. Those who clung to the thought of Athens in its days of military glory and empire, would painfully observe how great a change had taken place in the internal habits of the city. Formerly it was enough for the intellectual improvement of the youth, that in childhood he had the grammarian for his instructor, and as he grew up to manhood, was consigned to the poets;⁵

τοὺς μὲν γὰρ παιδαγωγῶσιν
ἔστι διδάσκαλος ὅστις φράζει, τοῖσιν δ' ἡδῶσι ποιήται⁶

Now even the slaves were becoming literary. The distresses of war had occasioned the addition to the roll of citizens, of many even from that class. And these might be seen, as the comic poet represents them, "each with his book, learning clever things;"

βιβλίον τ' ἔχων ἕκαστος μανθάνει τὰ δεξιὰ.⁷

Formerly, their wise men were obliged to leave the ignorance and rudeness of their own city, and learn philosophy by foreign travel. Solon had brought back with him from his travels the wisdom of Crete and of Asia to enrich their code of laws, but had not given philosophy a domicile at Athens; had not affected domestic life there with its refinements.

¹ Aristoph. *Ranæ*, 1487. ² Aristoph. *Aves*, 1282, 1554. ³ See Thucyd. iii. 82, ἐν μὲν γὰρ εἰρήνῃ καὶ ἀγαθοῖς πράγμασιν, κ.τ.λ.

⁴ In Xenoph. *Mem.* iii. 5, the younger Pericles asks Socrates how the Athenians are to be brought again to become enamoured of their ancient virtue, glory, and happiness; and afterwards he expresses his wonder how the state ever began to decline. Socrates imputes their degeneracy to their neglect of the institutions of their ancestors. The particulars mentioned are, want of respect to elders, neglect of bodily exercises, even to the ridicule of them, insubordination to authorities, mutual irritation, envy, quarrelsomeness, litigation, covetousness, incompetence of their generals.

⁵ If we except the profession of the Sophists, when at its height of public favour, skill in the composition of tragedy was the most highly rewarded of all talents at Athens. Plato, *Laches*, 183, b. p. 169. The poets of Athens, therefore, were naturally jealous of the popularity of philosophers and sophists.

⁶ Aristophan. *Ran.* 1052.

⁷ Aristophan. *Ran.* 1111.

Socrates. From that time, however, a change, introduced by the literary taste of Pisistratus, had gradually prepared the way for establishing a school of philosophy at Athens.¹ Pericles, too, had given a great stimulus to the literary spirit by his own fondness for intellectual pursuits, and the society of intellectual men. In the midst of his active political life, he could find time and thought for the elaborate disquisitions of the ingenious persons whom he invited to him. He could spend a whole day in disputing with Protagoras on so subtle a question as the theory of causation;² such was the intense interest which he displayed in every thing tending to the development of mental energy, and such the encouragement he gave to the change of taste then in progress by his own example. In the person of Socrates was found the genius formed to preside over the growing taste for literary and philosophical refinement, and to give it the form of an established institution. What, therefore, were merely indefinite fears at the time of the exhibition of "The Clouds," assumed a more distinct character of alarm to ancient prejudices within a quarter of a century afterwards. The rapidity and violence of several successive revolutions of the government during the latter part of that interval, further prepared the minds of the people for any sudden outbreaks of party spirit, and made every man an object of suspicion to his neighbour. A democracy of an hundred years' existence³ had been overthrown, and first an oligarchy of four hundred, then a tyranny of thirty, established by foreign arms, in its place. Nor, as it had not been without fraud and bloodshed that the people had been spoiled of their "ancient liberty,"⁴ were they disposed to surrender it in quiet; or were those who seized on the government able to retain it long on the same footing. A struggle ensued; in which the individuals of contending parties only sought to provide, each for his own aggrandizement and interest, or at least his own safety, under the constant expectation of some counter-revolution.⁵ The people had found that some of those very persons who would never have been suspected of oligarchical views, had in the late changes taken part against the popular government, so that they knew not, at last, whom to trust even of themselves.⁶ We are not to wonder that an accusation of Socrates should have succeeded before an Athenian jury at this period of morbid sensitiveness of the public mind.

An accusation of impiety was, we must remember, too, an accusation of a political offence. A change of the popular religion was a change of the fundamental constitution of a Greek state. And as in the absolute rule of a single despot, so in the tyranny of a multitude, the reputation of zeal for religion is studiously maintained from policy, if from no higher motive, to throw around its arbitrary acts the reverence and fear due to the religious character. The teaching of Socrates was indeed eminently religious, but it differed from what the state regarded as such. He proved the existence of an invisible divine power, wisely designing and governing all things, and inculcated the duties of piety and morality as flowing from the belief of such an agency. Such clearly was not the state-religion.⁷ This was no system of truth or morality. It was tradition and legend, and immemorial usage, and ritual observance.⁸ And it was enough for a charge of impiety that Socrates rested religion on other

grounds. A pious Athenian, and yet not pious after the manner of the Athenians, was, in their view, an introducer of new gods. He might well be believed to be a worshipper of the clouds and the air, when he pointed out to them, that the gods would not receive the sacrifice offered by wicked men,⁹ that even their silent counsels were not concealed from the divine cognizance, and that justice was an indispensable duty of the worshipper of the gods.¹⁰

That the accusation further should be credible, as brought in this form, is not strange, when it is known that, during the Peloponnesian war, the worship of new gods had been introduced into the city; as at Rome during the depression of its fortunes in the first years of the second Punic war. So greatly had the vicissitudes of fortune influenced the minds of men, observes Livy, describing this effect,—so great was the influx of religion, and that chiefly foreign, into the state,—that either the men or the gods appeared to have suddenly become different.¹¹ So at Athens, it appears, the forms of superstition had been multiplied, under the pressure of civil and domestic calamity acting on the fears and credulity of the people. The strong reproof which Euripides puts into the mouth of Theseus, of the austere life of Hippolytus, would seem to point at some ascetic devotees among the Athenians themselves, practising a more refined and scrupulous religion, distinct from that of the vulgar;

"Ἦδη νῦν αὖχεται, καὶ δι' ἀψύχου βορᾶς
Σίτοις καπῆλευ, Ορφέα τ' ἀνακτ' ἔχων,
Βάκχευε, πολλῶν γραμμμάτων τιμῶν καπνοῦς.¹²

In Aristophanes¹³ we find still more evident allusion to the introduction of new objects of worship, new fanatical rites, in which the women chiefly officiated, and in which a gross licentiousness mingled with the gloom and solemnities of barbaric superstition.

Again, education was intimately connected with politics in a Grecian state. The state took in hand its youthful citizens, and trained them according to its peculiar institutions, and in its own spirit. At least, in all the early constitutions, great attention was paid to education. Lycurgus made Sparta a constant school of war to his citizens. So too Solon, though he had, with greater knowledge of human nature than Lycurgus, adapted his institutions to the people for whom he legislated, provided that the people should be trained to the system of laws prescribed to them. But this care of the early legislators had begun to be lost sight of in practice.¹⁴ In Aristotle's day it had disappeared everywhere.¹⁵ In Sparta it was still nominally revered. In Athens, an entire relaxation of the educational discipline had taken place already in the time of Socrates. Pericles, flattering the democratic spirit of the Athenians of his day, could boast of their ease from labours and the obligation of exercises, and congratulate them on the courage which they could display at the time of action, without being inured beforehand by a course of hardy discipline.¹⁶ But now, whilst the state was remiss in not enforcing education according to its ancient system, a new system had grown up, the offspring of the luxury and refinement of its days of imperial greatness. This new and unauthorized education was diffused throughout the mass of the inhabitants beyond the pale of the citizens. Solon's law imposed the duties of

¹ Aul. Gell. vi. 17. Libros Athenis disciplinarum liberalium publice ad legendum præbendos primus posuisse dicitur Pisistratus tyrannus, &c.

² Plutarch in Pericl. Op. i. p. 665.

³ Thucyd. viii. 68.

⁴ Thucyd. viii. 71, 72.

⁵ Thucyd. iii. 82. πάντων δ' αὐτῶν αἴτιον, κ.τ.λ.

⁶ Thucyd. viii. 66.

⁷ Aristotle, Pol. v. 9.

⁸ Cic. de Legib. ii. 16.

⁹ Xenoph. Mem. i. 3.

¹⁰ Xenoph. i. 6.

¹¹ Liv. xxv. 1. Quo diutius trahebatur bellum et variabant secundæ adversæq. res non fortunam magis quam animos hominum; tanta religio, et ea magna ex parte externa, civitatem incessit, ut aut homines aut Dii repente alii viderentur facti, &c.

¹² Euripid. Hippolyt. 952.

¹³ See Pax. 410, 428. Lysist. 389.

¹⁴ Lysimachus, in the Laches, complains of their fathers having neglected their education, ὅτι ἡμᾶς μὲν εἶων τερυφᾶν, p. 162. See this dialogue of Plato throughout, on the subject of Athenian education.

¹⁵ Aristot. Pol. v. 7. ὀλιγαρχοῦσι πάντες.

¹⁶ Thucyd. ii. 39.

Socrates. the exercises on the citizens, but excluded the slaves from the gymnasium. Now all classes were hearers of the philosopher; the smith, the carpenter, the fuller, the dresser of leather, were engaged in discussing problems of ethics and politics, no less than the high-born and wealthy citizen, and the orator, and the statesman, and the general. This was an evident indication of a corresponding change in the government itself; a change, which really came to maturity not long after the time of Socrates, when the machinery of the government passed from the hands of the generals and the men of practical ability, into those of the orators of the republic, and when rhetoric, or oratory, became the master science, and only another name for politics.¹

Those, then, whose attention had been drawn to the person of Socrates many years before, and had then only laughed at the exaggerations of the comic muse, might naturally begin to suspect, in the progress of events at Athens, that there was a real danger to the institutions of the country couched under the humorous mien and conversation of the real Socrates. They would now, as they watched his increasing influence and reputation, recal their early associations of the ludicrous with the name of Socrates, not with the good humour with which they were originally received, but with the undefined fears since acquired, in the course of their daily observation, of one in whose hands the destinies of their country seemed to be placed. They would probably then think that they had judged his case too leniently before as spectators, and that they were now called upon to pronounce authoritatively as judges, not so much from the representations and arguments of the accusers, as from their own experience of the great change which their country had evidently undergone, and was still undergoing. Even indeed at the time of trial, nearly half of the great body of jurors were in favour of his acquittal; and Melitus would have failed altogether, but for the speeches of Anytus and Lycon, men of popular and rhetorical powers, who addressed the court in support of the charge; so strongly did the weight of his personal character, and the interest which he had excited by his friendly and instructive intercourse with every class of citizens, prevail in his favour.

We should take into account, further, the general neutrality of Socrates on questions of politics, and his decisive energy on particular political occasions, in which he was called upon by the circumstances of his position to take part. Both lines of conduct would create enemies. Neutrality in a state distracted with parties is the most unpopular course which can be adopted; however candid and reasonable the principle of such conduct may be, all parties look with jealousy at one who will not be associated with them in the guilt and the danger of party-struggles. They envy him his exemption from their violence, his reputation of candour, his safety under every vicissitude of party-ascendancy. Corcyra, as a state, was obnoxious to the other states of Greece for its neutral policy. So was the individual at Athens who kept aloof from public business, amidst that restless pragmatism which actuated the state and its citizens. Athenians could not understand and appreciate the motives of one who abstained from the public assemblies, and the courts, and the theatres,—who shrank from all public offices,—was a member of no faction or club,—engaged in no trade,—disregarded even his own domestic concerns,—and

lived a private man, where every one else was the servant of the public, busy with the affairs of the state, and incessantly pushing his own interests by his political activity.² The laws of Solon indeed inculcated the principle, that every one should take his side in the contention of parties.³ Solon wished to interest the people in the maintenance of the constitution which he had given them; and accordingly, obliged them by penalties to attend to public affairs. This was evidently his reason for compelling their attendance in the assemblies and courts, as also for this singular provision. The increased action of the democratic spirit in the time of Socrates must have greatly fostered the opinion thus declared in their ancient laws. And thus we find philosophers in general held in disrepute at Athens, on account of their inactivity and unconcern in public affairs. The busy sophist, the orator, and the man of the world, censured them as pusillanimous, and indolent, and incapable of the duties of a citizen. Some of the early philosophers, indeed, had been distinguished as statesmen, and legislators, and generals. The Pythagoreans in Magna Græcia appear still to have sustained this character in some measure. But now philosophers were observed, for the most part, to lead a contemplative life of leisure, and to present a striking contrast to the general society of Grecian states. Plato takes every opportunity in his writings of defending philosophy from this calumny directed against the persons of its votaries, evidently treating it as a grievance which he had felt in his own case. Aristotle also indicates the prevalence of the same objection against philosophers at his day, when he studiously maintains that exertions of the mind in mere speculation are to be regarded as even more really practical than those which are directed to external results.⁴ Socrates accordingly was a puzzle to many of his contemporaries. They wondered that he should freely dispense the treasures of his wisdom, and not convert it into a marketable commodity. Whilst they gave him credit for integrity, they regarded such a proceeding as mere folly.⁵ They asked how he could think to qualify others for public life, without taking part in it himself, if he really knew what it was to be a statesman. But he was content, in reply, to point to the number whom he had laboured to render capable of public duties, as a more effectual service on his part to the state, than a mere personal activity.

But though the general conduct of Socrates was to avoid all interference in affairs of state, he had shewn on one or two very important occasions his patriotic feeling, and the energy with which he could carry it into effect. He had served with distinguished courage at Potidæa, Amphipolis, and Delium, as we have seen; and proved himself, on those hard-fought days, one who, as Pericles characterizes the Athenians, could philosophize without effeminacy, and, without being inured to the dangers of the field, could brave them at the moment of trial with no diminished spirit. But still greater occasions of trial were those of civil exertion at home, to which he was called not long before the accusation of impiety. Perhaps one of the most memorable instances of resolute firmness which history presents, is to be observed in the fact, that when the uproar of faction was demanding the iniquitous condemnation of the generals who commanded at Arginusæ, Socrates stood alone among his colleagues in office, and refused to put the question to the vote, as the epistates, or superintendent of the

¹ Aristot. Eth. Nic. x. Τὰ δὲ πολιτικά ἐπαγγέλλονται μὲν διδάσκειν οἱ σοφισταί, πράττει δ' αὐτῶν οὐδεὶς, ἀλλ' οἱ πολιτευόμενοι, κ.τ.λ. Τῶν δὲ σοφιστῶν οἱ ἐπαγγελλόμενοι . . . οὐ γὰρ ἂν τὴν αὐτὴν τῇ ῥητορικῇ οὐδὲ χεῖρῳ ἐτίθεσαν. c. ult.

² Thucyd. ii. 40. ἐνὶ τε τοῖς αὐτοῖς οἰκείων ἅμα καὶ πολιτικῶν ἐπιμέλεια, καὶ ἑτέροις πρὸς ἔργα τετραμμένοις τὰ πολιτικά μὴ ἐνδεῶς γινώσκειν μόνον γὰρ τὸν τε μὴδὲν τῶνδε μετέχοντα οὐκ ἀπραγμονα ἀλλ' ἀχρεῖον νομίζομεν.

³ Plutarch, Solon, 20, tom. i. p. 354, ed. Reiske.

⁴ Aristot. Pol. vi. 3. Ἀλλὰ τὸν πρακτικὸν οὐκ ἀναγκαῖον, κ.τ.λ. Also Ethic. Nic. x. 7. The oration of Isocrates against the sophists is addressed to the same popular calumny against philosophy.

⁵ Xenoph. Mem. i. 6. Ὁ Σώκρατες, ἐγὼ τοι σὲ μὲν δίκαιον νομίζω, σοφὸν δὲ οὐδ' ὁπωστίουν, κ.τ.λ. . . . Καὶ πάλιν ποτὲ τοῦ Ἀντιφῶντος ἐρομένου, κ.τ.λ. Ibid.

Socrates. day, in the form proposed.¹ Each of the ten Athenian tribes had its turn of presidency in the council of Five Hundred for thirty-six days of the year; fifty out of the whole tribe being chosen by lot as its representatives during this period. These fifty were further subdivided into tens; and each of these tens, under the name of *proëdri*, served a week in succession, as it was allotted, until the official term of the tribe was completed. Again, of these ten presidents, seven were appointed by lot, to occupy the chair in succession during their week of office; each one of the seven becoming in his turn *epistates*, or superintendent for a day. The tribe *Antiochis*, to which Socrates belonged, happened to be the presiding tribe on the occasion of the impeachment of the generals; and it came to the lot of Socrates to be in the chair of office on the day when the question of their condemnation was so passionately debated. The generals had nobly done their duty to their country, and gained the most brilliant victory which had been achieved at sea in the course of the war by the Athenian arms. But the crisis was an unfortunate one for them. Athens was then on the verge of ruin. The jealousy of parties was at its height. The hopelessness of recovering the lost ground by military strength at this time, gave an opening and encouragement to personal intrigue, and the arts of an unscrupulous diplomacy; and a victory, however honourable to their arms, and hopeful as to the future, seems only to have been hailed with very doubtful congratulations by the struggling factions of the city; each looking at it rather as it might act for or against his party,—as it might tend to the strength of his rivals or their depression,—than as a great public triumph. However this may be, for the event remains a matter of perplexity to the historian, the successful generals were brought to trial through the treachery of their own officers, on the specious charge of having neglected the collecting of the dead bodies of their men after the action.² The charge was specious, because it was partly true, and was attested indeed by the very officers who were sent by them on that service, and who were now brought as witnesses against their commanders. It was true, so far as the endeavour to collect the dead bodies had been frustrated by a violent storm which followed the engagement. Still the endeavour had been made. The charge was further specious, because it appealed to religious prejudices, as well as to the democratic spirit. The generals seemed to have been regardless of the solemn rites due to the dead, and of the persons and feelings of the lower orders of the people. The occasion therefore furnished abundant topic of invective to the demagogues; and their addresses too fatally succeeded in obtaining an ungrateful and factious vote of death against the generals. Socrates was threatened with criminal information by the orators of the people; and the people themselves were urging on his assailants, and clamouring against him. Still he remained unmoved, and would not put the unjust question to the vote; preferring the hazard of bonds and death to himself, on the side of the law and right, to a compliance with the popular will in an illegal act.³ The iniquity was perpetrated ultimately in spite of his resistance; but he at least did his utmost to prevent it.

Such was his conduct under the ascendancy of the democratic power. Afterwards, when the oligarchy was established, and the Thirty were exercising their acts of cruelty and extortion without restraint, he was the first to give a check to their tyranny. In their career of confiscation and

blood, they marked out Leon of Salamis for destruction. Socrates. They conceived that the terror of their power would compel even Socrates to be a ready instrument to their rapacity; and they were desirous also doubtless to implicate him in the criminality of the act. Accordingly, they appointed him with four others to go to Salamis, and bring Leon to Athens, that he might be put to death. They were disappointed, however, in their expectation, so far as they depended on Socrates as an instrument in the dark deed. The order was executed, and the unhappy Leon was sacrificed to their cruel avarice and fears. But Socrates had no hand in it, and resisted it as far as he could. Unawed by their stern command, he said nothing, but as soon as he had left the *Tholus*, the place where the Thirty were assembled, he left his four colleagues to proceed on their bloody errand and went home. He would not, indeed, have dared thus to disobey the order with impunity; he would surely have felt their vengeance;—for there is nothing that tyrants resent more than a clemency volunteered by the ministers of their cruelties,⁴—but that happily that reign of terror was soon after put down.

By these intrepid acts, Socrates had shewn that the philosopher, in declining the contentions of political life, did not incapacitate himself for his duties when the exigencies of his situation should require him to perform them.⁵ As Thales had proved that the philosopher could, if he pleased, make money, by applying to that purpose his observations on the seasons, and his prognostics of an abundant crop of olives;⁶ so did Socrates defend philosophy in his own person, and by his conduct on these great occasions, against the imputation of inactivity and selfish ease. It is quite evident, too, that such a spirit as that displayed in these remarkable instances, had he entered into political life, would have subjected him to violent collisions with the successive leaders of party at Athens. "You well know, Athenians," are the words which Plato's "Apology" puts into his mouth, "that had I long ago attempted to take part in political affairs, I should long ago have perished, and I should neither have done you any service nor myself. And be not aggrieved with me for saying the truth. For there is no one of men that can be safe, in giving a spirited opposition either to you or to any other popular government, and in preventing the occurrence of many unjust and iniquitous things in the state; but he that would in reality fight for the right, must, if he would be safe but a little while, lead a private life and not engage in public business."⁷ "Think you, indeed," he further asks, "that I should have lived for so many years, had I engaged in public business; and had I, engaging in it in a manner becoming a good man, succoured the cause of right, and, as behoved me, made that the thing of greatest consequence? Far from it; for neither could any one individual of men."⁸

The time, then, appears to have arrived, when the accusation was brought by Melitus, for his exemplification of the truth of this observation in his own person. He had hitherto avoided the impending storm by the quiet tenour of his private life. But he had done enough to offend the partisans of either extreme in the state. Both extremes would be united against him in their enmity to all moderation; for the ascendancy of such counsels as his, would have been a death-blow to their own reckless lust of power. Hence, they were readily disposed to concur in sacrificing him to their mutual resentments. And we thus behold

¹ Xenophon, whose own reputation for courage gives a strong sanction to his opinion, says of this act of Socrates, *ἦν οὐκ ἂν οἶμαι ἄλλον οὐδένα ἀνθρώπον ὑπομείναι*, Mem. iv. 4, p. 208. He alludes in the same place to the story of Leon.

² Thucyd. ii. Plat. Apol. 28.

³ Herodot. Thalia, 3. 6. Cambyses was glad that his order, given in a moment of passion, to kill Cræsus, was not obeyed; but he could not forgive those who had ventured to reckon upon his return to better feelings; and he accordingly commands that they should be executed for their disobedience.

⁴ Plato, Apol. 32.

⁵ Cicero, De Divin. i. 49.

⁶ Plato, Apol. 31, 32.

⁷ Ibid.

⁸ Plato, Gorgias.

Socrates. the sad spectacle of one who had been the friend of every poor man at Athens, no less than of the rich and noble, requited with prosecution and death by those very hands conjoined in the unnatural act, which each should have warded off the blow inflicted by the other. The genius of Intolerance was indeed behind the scene, mixing the poisoned cup for its destined victim. But the actors on the public stage of the trial were, at the same time, wreaking their own vengeance on a political opponent; and the more exasperated against him, in proportion as, by his imperturbable demeanour and real inoffensiveness, he seemed to defy their assaults, and to throw them back on the consciousness of their injustice and ingratitude towards him.

Nor can there be any doubt, that there were many individuals, whose pride he had hurt, whose ignorance he had exposed, whose ill-humour he had irritated, and who, such is the infirmity of human nature, would rejoice in the opportunity of revenge by the verdict of a public condemnation of his doctrine. In affronting the sophists by his free discussions of their pretensions, he had excited, doubtless, the hostility of many of the higher order of citizens, their patrons and disciples. Many fathers of families too must then have been suffering from that corruption of public morals which, under the teaching of the sophists, had clothed itself with plausibilities of argument, and impudently arrogated, for its vain pretensions, the importance of philosophy. Disobedient, profligate sons, lifting their hands against their fathers, and adding bitterness to their unnatural rebellion, by the hollow false-hearted principles upon which they had learned to justify it,—forward, petulant youths, insulting the dignity of age by their pretensions to superior wisdom, and their turbulence,—these were the fruits of sophistical education, which came home to every family at Athens. Few that felt the evil in their own homes, would stop to inquire whether Socrates was the teacher whom they had to blame for their suffering. Most would hastily conclude, that all such instruction of the young was pernicious, and their offence at the mischievous doctrine of the sophists would become a disgust to philosophy and philosophers.

Some, indeed, would distinctly trace to Socrates the annoyance which they had experienced from particular individuals. There were many who had frequented the society of Socrates, with no sincere intention of profiting by his lessons,—who observed his inquisitive manner, and its effect in convicting and refuting the errors of those with whom he conversed, and who endeavoured, for their own wanton gratification, to imitate him in their intercourse with others. These would take delight in confounding and perplexing others, and exposing and ridiculing their pretensions to wisdom. It is easy to conceive, that the superficial resemblance to the manner of Socrates in these persons, and the vexation produced by it, would excite angry objection against the real method of Socrates.¹ These persons would be pointed at as his disciples. These would be referred to as instances of the evil tendency of the teaching of the philosopher himself; the discredit of the spurious disciples being reflected on the master, to whom it belonged not in any degree.

It appears, further, as might have been expected, that

the doctrines of Socrates were studiously misrepresented at the time. Allusions or illustrations employed by him in his reasonings were construed into positive opinions on the subjects to which he thus referred. For example, when, inculcating honest industry, he quoted Hesiod,² saying, "Work there is none that is a scandal, inaction is the scandal," the captious absurdly but maliciously interpreted him, as applying the words of the poet to sanction the doing every thing, whether right or wrong, for the sake of gain. When he quoted from Homer the account of Ulysses silencing the uproar of the people, against the practice of employing worthless persons in the public service, it was represented, that he approved the coercing the common people and the poor by harshness and violence.³ Again, in urging the necessity of looking to the qualification of those who should be appointed to office, and illustrating this by the fact, that no one would choose, by lot, a pilot, or carpenter, or flute-player, or any one, indeed, in matters where error was far less mischievous than in politics,—he was charged with encouraging contempt of the established laws, and exciting the young to acts of violence.⁴ And, (which is the most invidious form of misrepresentation), a general charge of corrupting the young was thrown out against him, unsupported by any specific statements of the means of corruption which he employed. As in the polemics of later days, so in the controversy between Socrates and his assailants, the obloquy of general hackneyed terms of reproach was resorted to as the substitute for definite grounds of imputation. Thus were the off-hand allegations against all philosophers,—“that they searched into the things in the air and the things under the earth, and rejected all belief in the gods, and made the worse appear the better reason,”⁵—used as a cover, on this occasion, to the envy and malignity which shrank from the light and the evidence of facts.

The accusation of Melitus, it will be observed, was distributed into three heads: 1. Contempt of the established religion. 2. The introduction of new divinities.⁶ 3. The corruption of the young. The second of these charges requires to be more particularly noticed, because it has reference to a peculiarity in the conduct of Socrates which gave it a colour of truth.

The mind of Socrates appears to have been deeply imbued with religious feeling. The observation of final causes particularly excited his interest; so much so, as to lead him to think that no other account should be attempted to be given of the phenomena of the world, but as they are the results of a wise and benevolent design. He delighted thus in contemplating every thing in a moral and religious point of view. He thought that the introduction of physical and mechanical causes into the study of nature, only perplexed and misled the mind. He had at first been greatly attracted by the speculations of Anaxagoras. What won his attention in the system of this philosopher, was its distinguished merit beyond all previous systems, in assigning mind as the master principle of the universe. But when he came to study the writings of Anaxagoras more closely, he was grievously disappointed, and threw up the system in disgust. For he found that it lost sight of the grand and true principle with which it set out, and, after all, constructed the universe out of mere material and mechanical elements.⁷

¹ Xenophon speaks of persons who were pointedly corrected by Socrates, μή μόνον ἃ ἐκεῖνος κολαστηρίου ἕνεκα τοὺς πάντ' οἰομένους εἶδέναι ἐρωτῶν ἤλεγχεν. Mem. i. 4. Such persons would bear a grudge against him, as Anytus in particular appears to have done, and would not be very scrupulous, with this angry feeling dwelling in their minds, as to the mode of resenting the affront.

² Op. 311. ἀεργείη δέ τ' ὄνειδος.

³ Xenoph. Mem. i. 2.

⁴ Plato. Euthyphro, 3, 6. ὥστ' οἷν καινοτομοῦντος σοῦ περὶ τὰ θεῖα, γέγραπται ταύτην τὴν γραφὴν καὶ ὡς διαβαλῶν δὴ ἔρχεται εἰς τὸ δικαστήριον, εἰδὼς ὅτι εὐδιάβολα τὰ τοιαῦτα πρὸς τοὺς πολλούς. Op. i. p. 6.—Xenoph. Mem. i. 2, 9.

⁵ Plat. Apol. 23, p. 54.

⁶ Athenians preserved the same character at the time of St. Paul in this respect, also, as well in their eagerness after news; as is seen in their accusing him of setting forth strange gods. (Acts xvii. 18.) ξένων δαιμονίων δοκεῖ καταγγελεὺς εἶναι.

⁷ Plato, Phædo.—Apolog.

Socrates. He saw, indeed, how futile, as to any real knowledge of the universe, had been the inquiries of the early philosophers. As an Athenian, he participated in that general prejudice against physical science, which Athenians had ignorantly imbibed against all philosophy, when they characterized it as idle talk and drivelling dotage. But as a genuine philosopher, in spite of his Athenian prejudices, he saw and felt that there was a real moral agency pervading the world; and he judged that, by observation of this, principles of real use for the right direction of human life might be discovered. Tinctured too, as an Athenian, with the superstition of his countrymen, and at the same time correcting it by his superior judgment and feeling, he was disposed to draw every phenomenon into his moral and religious theory of the universe. To stop to inquire into any thing whether it might be explained on simple natural causes, or to doubt its moral design, would appear to his mind as sceptical and profane. Hence, we see at once displayed in him the common character of the Athenian, in his dislike of physical science, and his susceptibility of superstitious influences from the most trivial things; and, on the other hand, the wisdom and religiousness of the true philosopher, in his constant devout disposition to refer all things to a providential design and moral agency.

It is well known how anxiously the heathens watched the most minute circumstances, not only in their religious rites, but in the actions of daily life, as intimations of the will of the gods. Not only dreams and visions, but flights of birds, the meeting any particular object, sneezing, a voice, or any sound, and the like trivial things, were regarded with seriousness and awe. Socrates felt the mystic influence of such incidents; only he thought more deeply on them than the generality, and that,—not with the vulgar emotions of fear or of hope, according as the omen might be interpreted,—but with calm and pious reference to the benevolent design which he attributed to them as divine intimations. Further, not only did he apply this sentiment to the outward circumstances of daily life; but he also took into his view the state of his own mind. He conceived that he received at times mysterious signs distinctly perceptible to himself, not indeed of any positive good to be expected from a particular course of conduct, but of precaution,—warnings against evil concerning others as well as himself. These presages he interpreted,—or others perhaps, taking his account of his impressions in too literal a manner, have so represented it,—as a voice addressed to him on each occasion. Instances too, are alleged in which this divine voice was the means of saving him and those who obeyed its direction, from danger. In the retreat of the Athenians after the unfortunate battle at Delium, it is said to have prevented his taking a particular road, and thus saved him, together with Alcibiades and Laches, from being pursued and overtaken by the enemy; whilst others taking another way were overtaken and slain.¹ This circumstance, according to Plutarch, was a great occasion of the fame at Athens of the “demonion,”—or “genius,” as it was called by Latin writers,—of Socrates.² To this voice is attributed his active devotion of his life to the moral reform of his countrymen by private and personal addresses to them, and his refraining at the same time from all political exertion.

The name of a particular dæmonion, or genius, was evidently not assigned by Socrates himself to these extraordinary presages, while he confidently declared their reality. It was rather the misconstruction of the vulgar, and of his

assailants, interpreting what he affirmed generally of divine intimations, as assertions of the presence of some particular divinity ascertained by his own convictions, and distinct from the gods worshipped at Athens. Heathens were incapable of forming a notion of the Deity, but as a local and tutelary god. They could not rise to the sublime conception of the one universal Being, τὸ δαιμόνιον, the God in all the world, than whom there is none else. In the view of Socrates, this belief in a presaging voice addressed to his private ear, was nothing more than an extension of the prophetic science, or divination of the heathen world, to practical purposes, and to the cultivation of religious feelings.

It must be remembered, that the Athenians had their augurs or prophets among the regular officers of the republic, without whose presence no matter of public counsel or of war was ever transacted. These were the recognized interpreters of the divine will. But Socrates claimed a special authority for the presages with which he was peculiarly favoured, and thus seemed to innovate on the science, and encroach on the established forms, of divination. He enjoined, indeed, a devout reference to the Delphic oracle, in all questions of hazardous conduct, teaching that, whilst human reason was the guide in all matters of human power, in those, on the contrary, which were out of human power, as the future event of actions, resort should be had to every means offered for exploring the will of the gods. He professed to have adopted his own course of life on the evidence of such communications. He advised Xenophon to consult the Delphic oracle, as to whether he should do well in accepting the invitation of Proxenus to join the expedition of Cyrus.³ But with this reverence for the recognized sources of divine information, he combined a suspicion of the pretenders to prophecy, who were countenanced by the popular superstition,—the θεομάντεις and χρησμοδοί,—who abounded at Athens.⁴ He relied rather on the sagacious auguries of his own mind, drawn from observation of some passing incident, or some rapid conclusion respecting the consequences of actions—a kind of intuitive judgment and forecaste, mingling and confounding itself with his religious impressions,—a second hearing, as it were,—a perception of a voice unperceived by the common ear, mysteriously telling of danger to come from some particular course of conduct. Thus was a pretext given to his enemies to say, that he introduced “new divinities;” whilst public opinion tolerated the grossest pretensions to divine revelations, and a system of mercenary imposture founded on them. Public opinion upheld the system of divination as it existed, with its external array of augurs, and prophets, and ceremonial. Socrates, on the contrary, led every man to consult the will of the Deity, not without devout preparation in the inward recesses of his own mind, nor without reference to his own obedience and moral improvement.⁵ Superstition, doubtless, strongly tinctured his notions of religious duty. This made him construe many things into divine intimations, which were frivolous and irrelevant. Still he rose above the superstition of the popular divination, in the personal piety which laid hold of each occasion for its exercise and cultivation, and taught men to regard the Divinity as interested in the protection of the good, and ever present to the words, and actions, and even the silent thoughts of men.⁶

Xenophon appears to have faithfully stated the difference between the popular divination and that professed by Socrates, in the following account: “He introduced nothing new beyond others who, acknowledging the reality of divination, make use of omens, and voices, and objects pre-

¹ Plutarch. de Socr. Gen. 298. Cicer. de Divin. i. 54.

² Xenoph. Anab. iii. 1, 4.

³ Plato, Alcib. ii. 150, p. 99. Καὶ γὰρ δεινὸν εἶη, εἰ πρὸς τὰ δῶρα καὶ θυσίας ἀποβλεποῦσιν ἡμῶν οἱ θεοὶ, ἀλλὰ μὴ πρὸς τὴν ψυχὴν, ἃν τις ὁσιος καὶ δίκαιος, κ. τ. λ.

⁴ Xen. Mem. i. 1, 19. Καὶ γὰρ ἐπιμελεῖσθαι θεοὺς ἐνόμιζεν ἀνθρώπων, οὐχ ὅν τρόπον οἱ πολλοὶ νομίζουσιν, κ. τ. λ.

⁵ Ibid. p. 299.

⁶ Plato, Apol. 22. c. p. 51.

Socrates. sented on the way, and sacrifices. For these do not conceive, that the birds, and the persons that meet them, know what is expedient to those who divine by them, but that the gods, by means of them, signify this. And so he held. But the generality say, that they are dissuaded and persuaded by the birds, and the objects that meet them; whereas Socrates spoke of it as he thought. For he said that it was the Divinity, τὸ δαιμόνιον, that gave signs to him. And to many of his intimates he prescribed to do some things,¹ to forbear other things, on the ground, that the Divinity had presigned it to him; and it was to the advantage of those who took his advice, whilst those who rejected his advice had to repent it."²

But how great was the change from the practical devotion of the mind here taught by Socrates, from that popularly entertained at Athens! The history of divination, as it was regarded, not at Athens only, but throughout Greece, is but a picture of the invidiousness and malignity of the human heart transformed into attributes of the Divine Being. Let us only hear Solon, as he is described by Herodotus, speaking of the Deity as a principle of envy and turbulence, and as guided by no fixed course in the disposition of human affairs; and we may judge what a task he had enteredprized, who entered into conflict with this inward and subtle idolatry of human passions, established by the heathen system of divination. It was indeed teaching divinities new to Athenian ears, when Socrates inculcated an inward reformation of the character of those who would look for the favour of the gods, or expect a special interposition and direction from the benevolent principle which guided the course of the moral world.

Whereas, too, the popular divination was employed on the most trivial occasions, and made the substitute for the proper exertion of men's faculties on matters cognizable by them, Socrates differed from this prevalent notion of the subject. He contended, that, where the line of conduct was plain, men should use the best of their judgment in acting,—that they should use their experience and reason in learning what the gods had given them to learn by such means, and only have resort to consultation of the Divine will by the extraordinary means of divination, where the results of conduct were uncertain. Thus might he be construed as dissuading men from the use of divination, when he only dissuaded from an improper use of it, and exhorted to a rational activity.

We may see from the story of Aristodicus of Cyme, how the practice existed among the Greeks, of endeavouring to obtain from the oracles sanctions even to iniquities and impieties. Aristodicus consults the oracle whether he may surrender an unhappy fugitive; and the oracle permits him, dexterously reproving, by the very permission, the attempt to cast the burthen of personal responsibility on the oracle itself, and to cover an immoral act with the veil of religious duty.³ Divination, in fact, was indolently resorted to in the heathen world, to relieve the mind of the labour and anxiety of thought, and the searchings of conscience. And Socrates addressed himself to the correction of this practice, by recommending, as we have seen, exertion of the judgment, and the acquisition of information on all matters within the sphere of human reason. He would thus provoke the hostility of many a professed diviner, who made a trade of his art, and would find individuals of this class ready to join in the outcry raised against him, of innovation on the popular theology.

The jealousy of the sophists in particular, the very class with whom the accusation of Melitus identified him, would also swell the popular envy against him on this head. For the sophists, among their pretensions, claimed to be regarded as endued with a predictive sagacity, so as to be expert practical guides respecting the future.⁴ Socrates would offend them in this point in two ways,—both as directing persons to have recourse to their own judgment, and the regular means of information on all ordinary questions to which human reason was competent; and as teaching a reference to a secret divine intimation on all other matters beyond the compass of man's understanding. For in both respects would the sophists find their course interfered with. The use of men's own judgment, or the appeal to the signs of the Divine will, would equally lessen the value for those counsels which they pretended to impart.

What added still further to this invidious feeling was, that the reputation of Socrates now eclipsed theirs throughout Greece. And Socrates appears himself confidently to have appealed to this public estimation of his character against the partial censures of his countrymen at the time of his trial. He vindicated his assertion of divine intimations specially granted to him, by referring to the oracle of Delphi as having honoured him with its distinct approbation. Chærephon, in the devoutness of his admiration of his master, had, on some occasion, consulted the oracle respecting him, and obtained an answer that Socrates was the wisest of men. The authenticity of the anecdote has been questioned. But the introduction of it in the two "Apologies,"⁵ may be taken as a voucher of its substantial truth. It at any rate shews the favourable opinion which had been conceived of him out of Athens itself; that, as Lycurgus had been complimented by the verdict of an oracle, so the same tribute of public applause might, with equal probability, be assigned to Socrates.

According to Laertius, the sentence of condemnation was carried by a majority consisting of 281 votes. The number was little more than sufficient to decide the question on that side; for it only exceeded the number of votes of acquittal by three. "Had but three votes only fallen differently," says Socrates himself, in the "Apology" of Plato, "I should have been acquitted." Nor, indeed, would Melitus alone, without the aid of Anytus and Lycon, (he is made there confidently to declare) have obtained even a fifth part of the votes to save him the penalty of a thousand drachmas, affixed by the law to an unsustained prosecution. But when the penalty of death was further put to the vote, and he was found unwilling to propose the substitution of any other penalty, such as a fine or exile, but evinced his indignant contempt of their unjust sentence, by asking rather, in his ironical way, instead of even a slight punishment, the highest honour of the state, that of a public maintenance in the Prytaneum, the multitude of the jurors was so exasperated by the unbending spirit thus displayed, that eighty additional votes were given on the hostile side, determining the sentence of death. So evidently was the whole case ruled by passion and the arts of demagogues exciting the people to treat it as a slight on their majesty, rather than as a cause in a court of justice. Otherwise it could not have happened, that when the previous question of guilt had been carried with nearly an equal number of dissentients, the severest penalty should have obtained such an accession of voices in its favour.

We have already remarked the little solicitude shewn by

¹ Xenophon here differs from Plato's Apology, in saying, that Socrates received intimations of what was to be done; whereas Plato expressly says the directions were only negative.

² Xenoph. Mem. i. 1, 3, p. 3. Xenoph. Apol. 13, ἐγὼ δὲ τοῦτο δαιμόνιον καλῶ.

³ Herodotus, Clio. c. 158, 159. The same is illustrated in the story of Glaucus in Erato, c. 86. The oracles were consulted, also, on frivolous matters, such as the petty thefts of Amasis. Euterpe, c. 174.

⁴ Isocr. c. Soph. 2, 4, περὶ τῶν μελλόντων μὲν εἰδέναι προσποιουμένους.

⁵ Xenoph. Apol. p. 249. Plato, Apol. p. 48.

Socrates. Socrates in regard to his defence from the accusation. As he strongly disapproved the affected artificial rhetoric of his times, and the practice of appealing to the passions against the judgment of the hearer, so neither would he study beforehand what he should say on the occasion of his trial. Twice had he essayed (he observes to Hermogenes) to consider what he should say in his defence, and as often had he been prevented by those secret divine intimations to which he habitually referred his conduct.¹ Nor again would he receive the proffered services of friends in pleading his cause. The celebrated orator Lysias composed an oration for this purpose. On reading it, he expressed his admiration of it, but declined it as unsuitable to him. When Lysias wondered that he could admire it, and yet say it was unsuitable, he observed, in his usual manner of illustration, by an apposite case; "Would not also fine coats and shoes be unsuitable to me?" Plato, however, it is said, could not be restrained from appearing in his behalf, and made an effort to address the court. But the uproar was so great, that on his uttering the words, "ascend the bema," he was met with the cry, "descend," and forced to abandon the attempt.²

So neither, again, would he resort to those appliances to the feelings which were usual in the Athenian courts. The Athenian jurymen expected that the defendant should come before him in the character of a suppliant, and entreat his clemency rather than claim his justice. He was to be assailed with prayers and tears, no less than with arguments addressed to his understanding. But Socrates would not condescend to these methods of persuasion. He would not produce his wife and children in the court, to excite compassion, or bring forward his connexions and friends to intercede in his behalf. He felt it unbecoming in him at his age, and with his reputation as a philosopher, to supplicate for his life. It would have given to his whole previous demeanour the appearance of insincerity and hypocrisy. It would have shewn that dread of death, against which all his teaching had been directed.³ It would have been an evidence that he disregarded the sanctity of religion, in trying to influence his jurors to decide by favour against their oaths, and so far would have substantiated the charge of Melitus against him.⁴ For the same reason, he had refused to offer to submit to a mitigated penalty, when challenged, according to the practice in the Athenian courts, to propose his own estimate of the offence. Afterwards, indeed, he softened this bold vindication of his merits, by adding, in the same ironical manner, that he could perhaps pay the fine of a mina of silver, and would therefore fix that amount of damages; or that as Plato, Crito, Critobulus, and Apollodorus, suggested the sum of thirty minæ, and would be good sureties for the payment, he would fix the latter amount.⁵ To have seriously proposed any such estimate would, in his opinion, have been an admission of his guilt.⁶

He displayed throughout the trial, the same calm and cheerful temper which characterized his ordinary behaviour. There were in his manner, even at that solemn crisis, touches of the same ironical humour, the same half-earnest, half-playful strokes of argumentative attack, which had given so much interest and point to his daily familiar conversations; and when the trial was over, he evinced no further emotion than the indignation of a sincere and honest man, at the malicious and mischievous arts by which the result had been accomplished. He was sustained by the consciousness that no crime had been proved against him; whilst his assailants must feel the reproaches of conscience for the real im-

piety and iniquity of which they had been guilty; some for having instigated others to bear false witness against him; some for having themselves borne this false witness. The disgrace of the condemnation fell not on him, he asserted, but on those who had passed such a sentence. He consoled himself with the thought, that it was the will of the Deity, and it was best for him now to die; that, though condemned by his present judges, like another Palamedes, he should receive from posterity that verdict of approbation which was withheld from Ulysses, to whose successful plot the life of that chief was sacrificed.⁷ Availing himself also of the prophetic power which the popular belief attributed to the words of a dying man, he warned his countrymen, as he left the court, that they were embarked in a course which must involve them in bitter repentance.⁸ He concluded his address with the following striking admonition: "I have only this request to make. As for my sons, when they shall have grown up, punish them, I pray you, by troubling them in the same manner in which I have been in the habit of troubling you, if they appear to you to concern themselves either with money or any thing else in preference to virtue. And if they would seem to be something when they are nothing, reproach them as I do you, that they take no concern about what they ought, and think themselves to be something when they are nothing. And if you do this, I shall have suffered justice at your hands, both myself and my sons. But it is now time to depart; for me to die, for you to live; but which of us is going to a better thing is uncertain to every one except only the Deity."⁹

In his way from the court to the prison to which he was now consigned, he was observed with eye and mien and step composed, in perfect unison with his previous address. On perceiving some of those who accompanied him, weeping, "Why is this," he said; "is it now that you weep? did you not long ago know, that, from the moment of my birth, the sentence of death had been decreed against me by nature? If, indeed, I were perishing beforehand in the midst of blessings flowing in upon me, it would be plain that I and my kind friends would have to grieve; but if I terminate my life at a time when troubles are expected, for my part I think you ought all to be in good heart, as feeling that I am happy."¹⁰ Apollodorus, whose admiration of his master amounted to an amiable weakness, complained to him of the great hardship of his suffering by an unjust sentence. Acknowledging the affectionate feeling thus shewn to him in a familiar manner, by passing his hand over the head of his attached disciple, he, at the same time, gently reproved him, saying, "Would you then, my dear Apollodorus, rather see me dying justly than unjustly?" and smiled at the question. On seeing Anytus pass by, he could not forbear, it is said, the expression of a strong censure on the conduct of that individual towards his own son. He foretold, what the unhappy result proved too true, that the heart of Anytus would one day be embittered by the evil fruits of that low and unworthy education to which, with mercenary views, he had subjected his son, a young man with whom the philosopher had formerly conversed, and who had seemed destined for better things.

The execution of Socrates, by the poisoned cup, would have followed immediately on his condemnation, but for the peculiar circumstances under which the trial had taken place. It was after the commencement of the Delian festival; an annual commemoration, of the safe return of Theseus and his devoted companions to Athens, from the fatal labyrinth of Crete, and the acquittal thenceforth of the

¹ Xenoph. Mem. iv. 8. "Εφη γὰρ ἤδη Μελίτου γεγραμμένου αὐτὸν τὴν γραφὴν, αὐτὸς ἀκούων αὐτοῦ πάντα μᾶλλον ἢ περὶ τῆς δίκης διαλεγόμενον λέγειν αὐτῷ, ὡς χρὴ σκοπεῖν ὅτι ἀπολογησεται, κ. τ. λ.—and Apol. 2, et seqq.

² Diog. Laert. in vit. Socr.

³ Plato, Apol. 38 b. Op. i. p. 88.

⁴ Plato, Apol.

⁵ Plato, Apol. Op. i. p. 79.

⁶ Xenoph. Apol. p. 23, κελευόμενος ὑποτιμᾶσθαι.

⁷ Plato Apol. ad fin.

⁸ Ibid. p. 82.

⁹ Xenoph. Apol. 24.

¹⁰ Xenoph. Apol. 27.

Socrates. bloody tribute exacted by Minos, by the mission of a vessel to Delos with sacrifices to Apollo, and other religious rites. When the priest of Apollo had once crowned the stern of the sacred vessel with the festive garland, it was not lawful to pollute the city by a public execution, until the solemn pomp should have been performed, and the vessel had returned. This ceremony had been performed only the day before the trial of Socrates. Thus he obtained the respite of thirty days between his trial and execution.

These were days of high interest and importance not only to his sorrowing friends, but to the cause of that admirable practical philosophy which all his previous life had inculcated. During this time he employed himself in literary exercises which he had never practised before. He composed a poem in honour of the god Apollo, whose festival was then in course of celebration. And feeling a religious scruple as to whether by the general pursuit of philosophy, he had fully complied with the suggestions of dreams repeatedly urging him, as he said, to "cultivate music," he now applied himself to the fulfilment of this supposed charge, by turning the fables of Æsop into verse.¹ But these were only pastimes illustrative of the serenity of his mind. Now, too, in his prison, with the chains on his body, and the near prospect of a violent death, he could discourse with an unanswerable cogency and eloquence of argument, of the vanity of human things, and the real happiness of man, as consisting in the cultivation of the spiritual and immortal principles of his nature. He had professed his whole life to be a meditation or discipline of death. He now had the opportunity,—which, as a philosopher, (could the voice of natural instinct have been silenced,) he would most have desired,—of realizing, by his own example, that death to which his thoughts and pursuits had been studiously directed. Unlike his successors in the schools of the Stoics, he did not advocate a doctrine of suicide, however he depreciated the importance of human life. With that good sense which restrained his religion and his philosophy from running into fanaticism, he held it to be impious in any one to release himself, by his own hand, from that post of duty in which the Deity had placed him.² Though, however, he had not courted death, or rashly placed himself in the way of it, he felt that, in the circumstances in which he was now placed, he was called to go through this last act of his philosophic profession. He seems, indeed, to have rejoiced in the opportunity thus afforded him of summing up his philosophy in one great principle, from which every observation and argument, in the course of previous teaching, had been drawn, by demonstrating, so far as reason could avail to demonstrate the fact, the absolute and eternal existence of the great principles of moral truth. The occasion was one which the genius of Plato would not fail to seize as most felicitous for the development of its own enthusiastic and transcendental view of the philosophy of Socrates. Plato, accordingly, has, in that most exquisite of his Dialogues, the *Phædo*, invited us to the couch of Socrates, on the last sad morning of his imprisonment, to listen to the philosopher, with the chill of death almost upon him, discoursing on the immortality of the soul. The affectionate and eloquent disciple doubtless shed natural tears over his dying master. But he wished also to elevate his own philosophy to the dignity of being the dying confession of the great sage of Athens. And he wished, further, that his own philosophy should speak, as it were, the funeral oration over him to whom it was indebted for its earliest inspirations, and pour its own libation on his tomb. Thus he has especially elaborated the last scene of his master's life, and made us contemplate with the deepest interest the death of Socrates, not only as an act

of heroic self-devotion and patient martyrdom to the truth, Socrates. taught by the great sage himself, but as a splendid episode in the dramatic development of his own philosophy.

During his imprisonment, Socrates was not denied the solace of receiving his friends, and conversing with them day after day. Early each morning might be seen a company of devoted friends, whom nothing could separate from him, assembled at the hall of justice, where the trial had taken place, and which was close to the prison, watching for the jailor to open the gate and admit them. Being admitted, they would commonly remain with him in the prison until evening, engaged in earnest and instructive conversation. His wife and children, too, appear to have been constantly with him.³ He was importuned by these affectionate followers to suffer them to effect his escape. Crito earnestly entreated him to be allowed to execute a plan which he had concerted for rescuing him. Simmias, the Theban, also brought a sum of money with him to Athens for that purpose. Cebes and others were equally ready with their resources. They argued, that, so far from being at a loss what to do with himself out of Athens, as he had said on his trial, they could ensure him friends in Thessaly, and many other places, who would most gladly welcome him, and protect him. But to none of these importunities would he yield. He answered, that, while he highly estimated their kindness, he was pledged to obey reason only, and that he saw no ground in his present circumstances for taking a different view of his case. As for the duty of providing for his children, by preserving his own life,—a consideration which Crito appears to have strongly pressed on him,—this was not now a matter for him to consider;—it was for those to consider, who, as his Athenian judges, treated life and death as such light concerns; for his part, he must look simply to what was right or wrong to be done.⁴ Thus steadily and calmly did he persevere in his resolution of awaiting the utmost extremity.

At length it was announced that the Theoric galley had been seen off Sunium, and might very shortly be expected to arrive at Athens. Crito proceeded in anxious haste to the prison, and being well-known to the jailor from his frequent visits there, obtained admission at a very early hour. He found Socrates asleep, and sat by him in silence, wondering to see him sleep so soundly in so much trouble, until he at length awoke to receive the fatal intelligence. This he received with the same composure as if it had been some ordinary communication. His only answer to Crito was, that he was quite resigned to the will of the gods, if it were so, but that he was persuaded by a dream, from which he had just waked, that the vessel would not come that day, but the following one. His reliance on dreams as divine intimations, has been already mentioned. He told Crito, accordingly, of his having dreamed that a woman of noble form, clothed in white, came to him and called him, and said to him in the words of Homer,⁵ "On the third day to deep-soiled Pthia thou shalt come." The event, at any rate, accorded with his expectation from the dream. On the morrow the vessel reached the harbour of Piræus; and the following day was appointed for the execution.

By the dawn of that day, the sorrowing party again met at the accustomed place, and were informed by the jailor, that the Eleven,—the officers who superintended the public executions,—had given orders that the chains should be taken off, and that Socrates should die on that day. After being kept waiting some time, they went in and found the philosopher already loosed from his chains, and sitting on the couch, with Xanthippe and his youngest child in her arms, by his side. By his desire they conduct her home, the kind Crito

¹ Plato, *Phædo*, p. 60 d. et seq.

² Plato, *Phædo*, p. 60 a. Op. i. p. 135.

³ *Ἡματί κεν τριτάτῳ Φθίην ἐρίβωλον ἴκοιο.*

⁴ Plato, *Phædo*, p. 61, c. *Ὁὐ μὲν ἴσως βιάσεται αὐτόν. οὐ γὰρ φασὶ θεμιτὸν εἶναι.*

⁵ Plato *Crito*, p. 48, c. Op. i. p. 111.

Socrates. entrusting her to the care of his attendants, amidst cries of passionate grief, which had broken forth from her afresh at the sight of them now come to bid their last farewell. The occasion naturally leads to the conversation which follows a discussion, according to Plato, on the immortality of the soul,—Socrates interrogating and arguing with all his wonted vivacity; whilst the party around him answer and listen with eager interest, and, as may naturally be conceived, with undescribable sensations of mingled delight and pain. Crito would have dissuaded him from this exertion, for he feared, from what he had been told by the executioner, that the heat of the body thus produced, would add to his discomfort in his last moments, by rendering the effects of the poison more lingering. He only observed, that “it mattered not; the executioner should only be ready to do his duty, and mix the draught twice, or even thrice over, if it should be found necessary.”¹

The discourse being brought to a close, he rose to proceed to the bath, as an immediate preparation for his death; when Crito detained him for a while, to ask his last commands about his children, or any other matter in which their services might gratify him. He replied, “that he had nothing new to say beyond what he had ever been saying,—that by attending to themselves, they would most gratify him and his, as well as themselves, in all they might do, though they might even make no promise now; but that if they neglected themselves, and were unwilling to follow in the track pointed out in all that he had said to them up to this last occasion, all that they could do would be of no avail, however much, and however earnestly, they might promise at the present moment.”² Crito assented to this advice, but in his eagerness still to do some act of kindness to his revered friend, subjoined, “But in what way are we to bury you?” This mode of speaking of his burial, gives occasion to a very characteristic reproof from him, of this solicitude on the part of Crito. “As you please,” was his answer, “if at least you can take me, and I do not escape from you.” Then gently smiling, and looking off to the surrounding company, he added, “I cannot, my friends, persuade Crito, that I am the Socrates that is now conversing, and ordering every thing that has been said; but he thinks that I am that man whom he will shortly see a corpse, and asks how you should bury me. But what I have all along been talking so much about,—that when I shall have drunk the poison, I shall no longer stay with you, but shall, forsooth, go away to certain felicities of the blest,—this I seem to myself to have been saying in vain, whilst comforting at the same time you and myself. Bail me therefore, to Crito the opposite bail to that which he bailed me to the judges; for he was bail for my staying; but do you be bail for my *not* staying when dead, but going away; that Crito may bear it more easily, and may not feel aggrieved for me, as if I were suffering something dreadful, when he sees my body either burning, or being interred; nor may say at the burial, that he lays out, or carries out, or inters *Socrates*. For,” he continued, turning himself again to Crito, “be assured, excellent Crito, that the speaking improperly is not only wrong in itself, but also produces some evil in the soul. However, take courage, and say that you are burying *my body*; and bury it as may be agreeable to you, and in the manner you may hold most lawful.”³

He then went into another apartment to bathe, Crito following him, whilst the rest of the party awaited his return. After bathing, he received his children,—two of whom were yet little ones, the third a youth,—and the females of his family. Having conversed some time with these in the presence of Crito, and given them his final commands, he dismissed them, and came out again to the assembled friends. This affecting interview had occupied a con-

siderable time, and when he returned, it was near sunset. Socrates. He had not long sat down, when the officer of the Eleven presented himself, and respectfully intimated to him that the fatal moment was at hand. The noble and gentle demeanour of the philosopher during his imprisonment had won upon this man; and used as he had been to the scenes of execration and horror within those walls, he was struck by the contrast in the case of Socrates, and bursting into tears as he gave his message, turned himself away, and retired. Socrates himself was touched by this demonstration of considerate feeling. He cordially returned the salutation, promising a ready compliance with the order. Then addressing the company, he observed, “How courteous the man is! through all the time he would come to me, and would converse with me sometimes, and was the best of men; and now how generously does he weep for me!” He then called for the poisoned cup. Crito’s affection would still have delayed it, for he urged that the sun was not yet gone down, and that others on the like occasions had not used such despatch, but had supped and drunk beforehand as they pleased. Socrates answered that this might be reasonable for others; for him it was reasonable not to do so; and persisted in requiring the cup to be brought. The process of bruising the hemlock took some time; but at length the man who was to administer the poison came with it now ready for the draught. He calmly inquired what he was to do; and, being told that he was only to walk about after drinking it, until he found a heaviness in the legs, and then to lie down, he took the cup into his hand without the slightest change of colour or of countenance. But before he put it to his lips, partly, it seems, from religious feeling, and partly in humour, he further asked whether he might make a libation to any one from the cup. Nor did even his usual quaint manner of putting a question, which he knew would somewhat surprise the hearer, forsake him on this occasion; for he looked at the man, at the same time, with that peculiar glance usual to him, which his contemporaries jocosely designated by a word denoting its resemblance to the manner in which the bull glares around him with the head downward. Learning that the whole draught was not more than sufficient for the fatal purpose, he said, “At any rate one may, and ought to pray to the gods, that the migration hence to those regions may be prosperous; which indeed I do pray, and so may it be!” With these words, he drank off the poison with the most perfect composure and readiness.

At the sight of this, the bystanders could no longer command their emotions. Their tears flowed profusely. Some rose up from their seats,—Crito set the example,—and covered their faces, to give vent to their sorrow. Apollodorus sobbed aloud. He gently expostulated with them for this outbreak of grief, saying, “What are you doing, my friends, so strangely? I indeed sent away the women not least on this account, that they might not offend in such a way; for I have heard that one ought to die amidst auspicious sounds: I pray you, therefore, be tranquil, and bear up.” This rebuke had the effect of repressing their tears. The heaviness which he had been led to expect from the working of the poison now began to come on, and he left off walking, and reclined, with his face upward, and covered over. The torpor gradually spread towards the upper regions of the body,—the lower parts becoming, one after the other, congealed, and insensible,—until it reached the heart. In this interval, he uncovered himself, and said, “Crito, we owe a cock to Esculapius; pay it, I pray you, and neglect it not;” intimating probably that now all the diseases of life were healed, and that he was restored to real and pure existence by the death of the body. These were his last words. Crito asked whether he had any thing more to say, but received no answer. There was no further indication of life,

¹ Plato, *Phædo*, p. 63, d. *et sqq.*

² *Ibid.* p. 115, a. *et sqq.*

³ *Ibid.*

Socrates. but a motion of the body. The executioner uncovered him, and they observed his eyes fixed; upon which Crito, faithful in the last respectful attentions to his beloved friend, the now departed philosopher, closed the mouth and the eyes.

Thus died Socrates, when he had now completed his seventieth year, B.C. 400, or 399, in the full vigour of a healthy old age; happy in his own estimation, and in that of his admiring disciples, in having terminated his life in so glorious a manner, with unimpaired faculties of mind and body, and after a defence sustained with so much truth, and justice, and fortitude.¹

His death spread dismay at the moment among those who had been most conspicuous in their attachment to the philosopher, as they naturally dreaded the overflowings of that malignant spirit which had swept down their master. The chief of these appear to have fled to Megara, where they could reckon on finding a refuge from Athenian hostility, and a home with their fellow-disciple, the friendly Euclid. It is remarkable, however, that Isocrates, timid as he was by nature, should not have scrupled to remain at Athens, and to testify his affectionate regret for his master, by appearing the next day in public, clothed in mourning.² But with the fall of its great victim, the spirit of persecution was sated for a time. An act had been perpetrated, to which the eyes of all Greece would be intently turned; and the greatness of the sacrifice seems at the moment to have absorbed the attention of its agents and instruments, in the contemplation of it and its possible effects. If we may believe the representation of subsequent writers, shame and repentance soon followed the cruel act; and those who were most ostensibly involved in its guilt, were either banished or sentenced to death, or laid violent hands on themselves. Of the banishment of Anytus, and the death of Melitus, we are told by Laertius, that Antisthenes was the immediate cause. In what way he was instrumental to the death of Melitus, is not stated. But with regard to Anytus, Antisthenes is said to have occasioned his banishment, apparently without the intention of doing so, by a stroke of practical humour. For meeting with some young men from Pontus, inquiring for Socrates, whose fame had induced them to visit Athens, he conducted them to Anytus, who, as he observed to them, was "wiser than Socrates;" upon which, the indignation of the bystanders was excited, and they drove Anytus forth from the city.³ He fled to Heraclea; but there found no peace, being forced by public proclamation to leave the city forthwith.⁴ Though, however, these individuals soon after received the retribution due to their offence, it would not follow that they suffered from their countrymen on account of the part they had taken against Socrates. The ascendancy of another political faction, (and Athens was ever fluctuating between contending parties), would be quite sufficient to account for their overthrow and desperation. On the other hand, the testimony of Plutarch is explicit to the point, though he mentions no individuals by name, that the sycophants who had assailed Socrates became the objects of popular hatred to such a degree, that none would associate with them in any way, not even to return them an answer when addressed by them, and that at last they hanged themselves, being no longer able to endure the public execration.⁵ His friends, indeed, performed the last obsequies to his remains; but his fellow-citizens afterwards concurred in honouring him, by erecting a brazen statue of him, the work of Lysippus, in the Pom-

peium, and expressing their sorrow, by closing the public gymnasium for a while.

This at any rate is certain, that persecution, as it ever does, overwrought its part in the case of Socrates. It oppressed, indeed, the individual, but it gave the seal of martyrdom to the cause in which he had been engaged. It produced a temporary intimidation, under which men would hear less of the name and teaching of Socrates openly avowed, but throughout which the admiration and love of the heroic philosopher would be cherished in secret, and his doctrine would be fostered in the shade, to appear in the sunshine of a future day. If the Athenians had desired to plant the root of philosophy in their city, they could not more effectually have done so, than by their violence against Socrates. Such, in fact, was the result. Philosophy henceforth obtained an Athenian naturalization and name; and the schools of Athens may date their period of nearly a thousand years from this memorable act, which, in its intent and spirit, fiercely but blindly endeavoured to extinguish there the very profession of philosophy.⁶

The cause, however, in which Socrates had been engaged, was too true, for any opposition to it, though conducted with the greatest prudence, to have been long successful. It had also already advanced too far, and interested too many persons in the maintenance of it, to be put down by a sudden blow. The burning of a book, or a formal condemnation of the opinions of a writer, are but futile means, as experience shews, of suppressing obnoxious doctrines. How much less could opposition avail, where, as in the case of Socrates, the offending doctrines had been scattered over, not the pages of a book, but the strenuous exertions of a long life,—already engraved in characters which no obliterating hand could reach, and doubtless so worked into many a mind, as not to be distinguishable from its own proper convictions,—doctrines too, so confirmed by the noble example of their teacher, in carrying them out to their full consequences by his death? For the death of Socrates, it should be observed, was not simply a test of his sincerity in his teaching. It was this, and still more. It was the ultimate and decisive opposition to those false principles, against which every action and discourse of his life had been directed. He had been all along exposing the presumptuousness and vanity of the principles on which men ordinarily judged and acted. He was now further to shew, that this opposition on his part was not to be daunted by those principles, when set in formidable array against his own life; and that, professing a low estimate of the present life, he would not disown or shrink from that profession at the moment of greatest trial.

If we inquire, accordingly, what was the substance of the positive teaching of Socrates, we must address ourselves to the contemplation of his active life, and his resigned patient death. He had no design of establishing philosophy as a literary pursuit or intellectual pastime; though he probably foresaw, that that taste for inquiry into truth which he was ever awakening, must soon lead to the formation of a philosophical literature at Athens. He already witnessed, indeed, the commencement of such a literature, the result of this excitement, if it be true that he had read the *Lysis* of Plato, and observed respecting it, "How much the young man makes me say that I never said!"⁷ He wished rather to divert men from the vanity of setting themselves up as philosophers, and make them employ their thoughts in learning and investigating, instead of prematurely commencing

¹ Xenoph. Mem. iv. 8.—Apol. 32.—Plato, Phædo, ad fin.

² Diog. Laert. in vit. Antisth. vi. 4, 10.

³ Plutarch. de Invid. et Od. Op. viii. p. 128.—Diodorus Siculus says, ὁ δῆμος μετεμελήθη . . . καὶ τέλος ἀκρίτους ἀπέκτεινε. xiv. 38; also Augustin. de Civ. Dei, viii. 3.

⁴ The schools of Athens were closed in the reign of Justinian, A.C. 529.

⁵ Pseudo-Plutarch. X Orat. Vit. Plutarch. Op. ix. p. 336.

⁶ Ibid. in vit. Socr. ii. 5, 43.

⁷ Diog. Laert. in vit. Plat. xxiv.

Socrates. at once as well-informed persons and teachers of others, with crude and superficial notions and principles.

If we look, then, to the course of his practical teaching,—to the general tenor of his conversations and actions, and the example throughout of his life and death,—we shall find that his whole labour was directed to the establishment of true moral and religious principles, in opposition to the false and mischievous principles which, he observed, were commonly acted upon and avowed in the world. The excellence and supremacy of self-knowledge was what he was ever inculcating; and of self-knowledge, not as a matter of intellectual curiosity, or for its value as a science, but in order to self-government and to happiness. He found that this was the last kind of knowledge which men ever thought of acquiring; that they had, in fact, no concern about it; or that if they were reminded of its necessity, they presumed on their possession of it already. His first effort, then, was to open the minds of men to a perception of the value of this knowledge, and of their own need of it. The questions which he would put—the refutations which he addressed to the various propositions or conclusions elicited from others in the course of his conversations—the perplexities to which he would reduce them—and the unsatisfied state in which he would commonly leave them, after exciting their doubts—all had a direct tendency to convince men of the insufficiency of their intellectual acquirements, and of their want of some more adequate and availing information.¹ To the same purport was his disparagement of physical science, and of all merely speculative knowledge, in comparison with that which was useful for human life. For he was far from an utilitarian, in the modern sense of that term. He did not value particular studies, because they ministered to the necessities or conveniences of human life, or undervalue them because they had no such bearing. But he saw that his clever and ingenious countrymen were studious of intellectual refinement—that they delighted in the specious, and the admirable, and the subtle, more than in the solid and the unostentatious qualifications of the good member of a private family and the useful citizen. He was aware, too, from his own acquaintance with the existing physical philosophy, how imperfect that knowledge was, how entirely hypothetical, and incapable of practical application. We must make allowance, therefore, in estimating his objection to speculative science, for the polemical spirit in which he assailed a branch of knowledge then, at once, so barren, and so encroaching in its claims on public attention. We must regard him as preparing the way for the due cultivation of the other, the higher as well as more important knowledge, that of man's own nature, then so little thought of, and so neglected. This seems to be invariably his design on every occasion, whatever may be the immediate purport of his discourse.

When he came to direct the minds of men, once awakened to the importance of moral study, to the subject itself of human nature, he had to encounter on the very threshold the most perverse notions. All their maxims of life were based on the absolute importance of the present life. The body, and its present appetites and desires, were regarded as the whole of man. The tyrant, in the enjoyment of absolute power to gratify every passion without restriction or penalty, was considered as the apt representation of the highest human felicity. All men's plans of life accordingly were directed to the acquisition of power for themselves. They studied to improve their external circumstances, and not themselves. Then their religion was merely the fear of mysterious powers influencing the prosperous or adverse events of the present world, and which

were therefore to be conciliated or appeased by offerings and vows. Socrates set himself strenuously to refute these vain presumptions. He argued the folly of supposing, that men really accomplished their own wishes in gratifying each prevailing inclination. He showed, that whilst they did what they pleased at the moment, they did not in fact attain that pleasure which they sought; and led them therefore to surmise, that there must be some end of human pursuit beyond the gratification of the passions, and further, some ultimate end to the whole sum of the active energies of the soul, beyond the present life, and distinct from all bodily associations. But he not only suggested such a thought by shewing the reasonings on the opposite view of human life to be inconsequential and absurd; he further practically refuted the prevailing fallacies on the subject, by his own example on the other side. He proved to the world, by divesting himself of all the worldly accessories of happiness, and depending exclusively on the internal resources of his mind and character, and by his perpetual cheerfulness under those privations, that happiness did not result from externals, or from the body, but from the internal nature of man, nor from any thing positive and absolute in that nature, so much as from its state of discipline and command over the appetites of the body. Theories of morals were yet to be formed. It remained for Plato to erect the true and sublime standard of human conduct in the perfections of the Divinity, and for Aristotle afterwards to shew the application of the law of habits to the subject. Socrates has the merit of having prepared the way for these developments of the subject, by demonstrating the folly of seeking the ideal of happiness in any enjoyment of the body, or in any thing present.

So also as to religion, though he could not advance, in his conceptions of the retributive justice of the Divine Being, beyond the circle of darkness which limits the natural observation of man, he proved the absurdity of supposing that mere external punishment was the only suffering undergone for offences committed. Secret faults, as he pointed out, did not escape with impunity. He appealed to the remorses of conscience, to shew how surely, however invisibly, wrong doing was visited with its punishment; and whilst in his own mind he concluded that there would be a future state, in which each man would receive the merited consequences of his actions, he must also have excited, in the minds of his hearers, a strong though undefined apprehension of a period of general retribution after death in another world. At least they must have seen that it was not so certain, as they may have once supposed, that though a present punishment may have been evaded, punishment would not follow at a future day. In well-disposed minds, there would thus be a foundation laid of a doctrine of the immortality of the soul. Under the teaching of Socrates himself, this truth, perhaps, would scarcely assume the form of a doctrine, so distinctly as it is stated by Plato. It would be simply a practical conviction. And thus Socrates himself probably scarcely propounded it in formal terms, nor without those qualifying doubts which both his memorialists describe him as joining with its enunciation. But Plato, following him, took up the doctrine as a formal truth, and worked it up into a perfect theory, with the formal array of argument and didactic exposition.

There was nothing, indeed, of system in any part of the teaching of Socrates. In the "Memorabilia" of Xenophon, we have probably a very complete specimen of the substance of what he taught, and, in the desultory manner in which the subjects of the several conversations there given are introduced, of the actual way in which he would throw

¹ Xenoph. Mem. iv. 3. 36. Ἄλλα ταῦτα μὲν, ἔφη ὁ Σωκράτης, ἵσως διὰ τὸ σφόδρα πιστεύειν εἶδέναι οὐδ' ἔσκεψαι. . . . Ib. 39. φροντίζω, μὴ κράτιστον ἢ μοι σιγῶν κινδυνεύω γὰρ ἀπλῶς οὐδεν εἶδέναι.

Socrates. out his questions and reflections on different points, as they happened to suggest themselves on each occasion. There we find the various duties of the good man and the good citizen summarily sketched, without the formality of statement or systematic connexion. He inquires what is just, or pious, or temperate,—and he leads his hearers to consider the true definitions of the several virtues;¹ but it is chiefly with the view of laying open their mistakes and confusion of thought on the subject, and to divert them from sophistical disquisitions on virtue, to the discharge of virtue in all its parts, rather than to give any precise idea of it himself.²

Certainly there are grave objections to the morality which he taught. It did not enjoin that perfect purity of sentiment and action, which, judging from its general excellence, we might perhaps have expected. It forbade excesses of licentiousness as evil, but it did not also forbid licentious indulgence as altogether vicious, or fix its stigma on those monstrous forms of vice which polluted Grecian society. Nor, again, did it give a right tone to the resentful feelings. It enjoined the requiting of ill to enemies,—placing retaliation as a duty on a par with the return of kindness to friends.³ With these exceptions, the morality inculcated by Socrates, founded as it was on the indications in man's nature of a destiny beyond the present world, bears strongly the marks of the law written by the finger of God, and proves that the Creator has not left Himself without witness, where the light of his revelation has not shone. Supposing even that those great truths, thus taught, were the broken planks from the wreck of a primitive Faith, floated down on the stream of ages, we must yet believe a providential disposition, in the fact of that ready acceptance which they could obtain with one, brought up, as Socrates was, amidst the grossest corruptions of heathenism. His was an instance, how the unsophisticated heart responds to the notices of divine truth, when once they are duly presented to it; and how, wherever there is a sincere pursuit of right, the moral eye will be enabled to pierce the surrounding gloom, and to discern, for the most part, the true outline and form of right.

It is observable, however, that, whilst Socrates correctly perceived that the laws of religion and morality possessed a sacred importance, independently of all positive enactments of men, he yet appeals to the laws of the state for the particular rules of religious and moral duty. When instructing Euthydemus on the worship of the gods, he cites the Delphic oracle, which enjoined the law of the state as the rule of acceptable worship.⁴ When asked by the sophist Hippias what is just, he answers, that it is what the laws prescribe. Such reference was perfectly natural in a Greek, accustomed as Greeks were to view every thing in subordination to politics, and to regard the duty of the citizen as paramount to every other duty. This feeling had its influence with Socrates, and induced him to regard the authority of the state as possessing in itself a moral force of obligation. The respect which he throughout shewed to the laws of his own state, was that of one who

not only obeyed what they commanded, but strictly revered their authority.⁵ We must not, however, suppose, that he thus intended to place positive and moral laws on the same footing. The reference which he gives to the written law of the state, as the directory on questions of religion and morals, is the substitute in his teaching for a systematic development of the moral and religious duties. The law of the state presented, to one who had no thought of systematizing the subject for himself, the best expression of those great truths which he was drawing forth from the higher source of man's eternal nature. He is content to point out to his hearers, in a general way, the wisest and readiest collection of rules for those cases which came under the great comprehensive duties of piety and justice. Evidently he is not treating the subject with the exactness of the theorist, in assigning this importance to the law of the state; but he is enforcing the use of the law of the state as an authoritative practical guide to right conduct.—His internal view of religion, for example, was founded on observation of the signs of benevolent design throughout the material and intellectual world; and he was thus led to the acknowledgment of a pure Theism. But in his conduct, he knew not how to realize the obligations which the perception of this truth imposed on him. With his reverence, accordingly, for the laws of his country, as well as under the influence of that superstition to which his piety habitually verged, he sought a direction to his religious sentiments from the authority of the state, and thus in practice was a polytheist.—His object was further to prevent men from trusting to the conceits of their own judgment in matters of conduct, and to recommend a proper deference to the wisdom and authority of their ancient laws, then so presumptuously slighted by each vain pretender to superior prudence and political sagacity.

In assailing, as Socrates did, the follies of his countrymen by the dexterity of an acute reason, he was ever exposing their ignorance. The impression on his own mind appears to have been, that men erred rather from the want of due information respecting their moral condition, than from the perverseness of their will,—from folly, rather than from vice. Himself an accurate observer of human life, and with a disposition to follow the path of duty wherever it might lead him, he had in his own case felt the importance of intellectual cultivation, in order to right conduct. From his own circumstances, accordingly, and a natural predilection for those exercises of the mind which were his habitual pursuit, he overrated this importance; and, instead of simply regarding the information of the mind as a necessary ingredient in moral improvement, he made it all in all. Thus, according to him, wisdom or philosophy was virtue, and ignorance and folly, vice. He carried this view of morals so far, as to place the knowledge of duty on a footing with the knowledge of arts. Nor was he even startled with the paradox, that if such were the case—if the knowledge of right were the whole of morality—there would be less immorality in intentional wrong conduct, than in unintentional done through ignorance.⁶

¹ Xenoph. Mem. iv. 8, 11. 'Ικανὸς δὲ καὶ λόγῳ εἰπεῖν τε καὶ διορίσασθαι τὰ τοιαῦτα, κ.τ.λ.

² Xenoph. Mem. iv. 4, 9. 'Αλλὰ μὰ Δι', ἔφη, οὐκ ἀκούσῃ, πρὶν γ' ἂν αὐτὸς ἀποφύγῃ, ὃ τι νομίζεις τὸ δίκαιον εἶναι. ἀρκεῖ γὰρ, ὅτι τῶν ἄλλων καταγελάς, ἐρωτῶν μὲν καὶ ἐλέγχων πάντας, αὐτὸς δὲ οὐδενὶ θέλων ὑπέχειν λόγον οὐδὲ γνώμην ἀποφαίνεσθαι περὶ οὐδενός, κ.τ.λ.

³ Xenoph. Mem. iv. 2, 16; ii. 6. 35. Aristot. Rhet. ii. 23.

⁴ See, in the "Crito" of Plato, a beautiful address, put into the mouth of Socrates, from the personified majesty of the laws.

⁵ Xenoph. Mem. iv. 2, 20. Δοκεῖ δὲ σοὶ μάθησις καὶ ἐπιστήμη τοῦ δικαίου εἶναι, ὥσπερ τῶν γραμμάτων, κ.τ.λ. Seneca, arguing also the need of moral information for the performance of duty, refers to the same illustration of morality from the arts, as that given by Xenophon, to shew that there is no real analogy between the two subjects. "Vis scire," he says, "quam dissimilis sit harum artium conditio et hujus? In illis excusatus est, voluntate peccare, quam casu: in hac maxima culpa est, sponte delinquere. Quod dico, tale est. Grammaticus non erubescit solecismum, si sciens facit: erubescit, si nesciens. Medicus, si deficere ægrum non intelligit, quantum ad artem, magis peccat, quam si se intelligere dissimulat. At in hac arte vivendi, turpior volentium culpa est." Ep. 95. 8. He seems to have had the argument of Socrates, as given by Xenophon, (Mem. iv. 2, 20.) in his view. So also Aristotle says: Καὶ ἐν μὲν τέχνῃ ὁ ἐκὼν ἀμαρτάνων αἰρετώτερος περὶ δὲ φρόνησιν ἦττον, ὥσπερ καὶ περὶ τὰς ἀρετάς. Eth. Nic. vi. 5.

⁶ Ibid. iv. 3, 16. Also, i. 3, 1.

Socrates.

Thus vice was in no case, in the view of Socrates, an act of the will, but of the mistaken judgment. He did not mean by this to assert, that men did not act wrong wilfully in the particular instances of misconduct, so as not to deserve blame for their misconduct; but that the seat of vice was in the perverse understanding,—for that the will was invariably towards good. If, accordingly, vice may be regarded as seated in the understanding, and not in the heart, it would follow, that that man is less vicious in principle, who knows what is right and acts wrong, than one who acts wrong without knowing what is right. The former alternative, however, was impossible, according to his theory. For knowledge, by its intrinsic excellence, must prevail over every other principle. So far was Socrates led by the working of his method, and his observation of the ignorance and folly of men, to overlook facts, at least, as evident on the other side,—the plain instances of men acting wrong in spite of their better knowledge, and of greater blame assigned to wrong thus done in spite of knowledge. His error is further to be traced to a confusion of the ideas of right and happiness, in the term “good.” That the will is, by the original constitution of man, invariably towards good, if we take good in the sense of real interest or happiness, is quite true; but it is far from true, if we include the notion of right in that of good. Men, when they take even perverted views of their happiness, may be regarded as unconsciously desiring the real happiness of their nature. The will, therefore, in this sense, may be said to be always towards good. But in the latter sense of the term “good,”—that in which it includes right,—the contrary rather is true. Men see the light, but love darkness rather than light; and the seat of vice is, accordingly, not in the understanding, but in the heart. But there is this justification of the language of Socrates on moral subjects, that the ignorance which he attacked, was, in truth, a vicious and blameable ignorance. Men did not take pains to inform themselves on moral subjects. They neglected themselves, pursuing and professing every other kind of knowledge but that which was most at hand for their acquisition, and most concerned them. Seeing, then, the moral errors into which men ran from this neglect, Socrates not unreasonably set his mark of reprobation on ignorance, as the source of immorality. Immediately, indeed, and ostensibly, he attacked the general ignorance of men, holding out philosophy as the remedy of vice and unhappiness. But the ultimate and real object of his attack all the while was, the immoral disposition, the self-neglect, and the irregular habits of life, from which the incapacity and ignorance of men on moral subjects commonly result. Then, further, it was the ignorance of self, chiefly, that he laboured to remove. He found conceit as to themselves, the prevailing fault of the men of his age and country. And he hoped, by exposing their ignorance on various subjects, to make them question their presumptions relating to their own nature, and character, and duties. Thus would he, in effect, be correcting moral error,—the folly of men persuading themselves and others that they knew what they had never cared to examine, much less to know.¹

As the peculiar aspect under which he presented the subject of morals arose, in a great measure, from his manner of interrogating in conversation, so the general character of his philosophy is to be sought in its intimate connexion with the peculiar method which he pursued. His philosophy, being essentially colloquial, laid down no positive principles in any particular science, or even any general principles for the conduct of the understanding in scientific or

moral inquiries. But it sought to rouse the understanding to a perception of its condition of weakness, and defects, and ignorance, previous to its interrogation of itself, and its acquisition of knowledge, and its strengthening by exercise and discipline. Like the great reformer of modern science, he found nothing duly ascertained in the field of philosophy; hypotheses assumed without examination, truth obscured and confounded under the plausible cover of general terms and vague analogies. Yet every one was fully satisfied with the state of knowledge; every one presumed that he was in possession of the truth. So, too, at this period, as at the time when Bacon proposed his new method, there was a dialectical science in use, available only for disputation and victory, and not reaching the truth of things, or imparting any real knowledge. And, in like manner, in the time of Socrates, as in that of Bacon, this imperfect dialectical science was regarded as the key to every kind of knowledge; and he who could discourse fluently on any given subject, was esteemed the accomplished philosopher. “Of nothing,” as Bacon himself pointedly observes, “were men so scrupulous as lest they should seem to doubt on any subject.”²

This state of things formed a strong barrier against any attempt to effect a moral reformation. The way to the heart had to be cleared through a mass of outworks thrown out by the intellect. It only remained, then, for him who would be the moral reformer of his countrymen, to work by means of that very dialectical science which opposed its ramparts and its arms to his progress.

But to have simply used the same method which his contemporaries employed, would have been to revolve in the same perpetual circle. Socrates, indeed, might, by a more skilful use of the same dialectical artifices, have confuted the sophists and others with whom he reasoned. He might have gained the victory in argument, by demonstrating the fallacy of their deductions, or proving the contradictory of their conclusions. But no advance would have been made by such a proceeding towards a detection of the source of the popular errors, the wrong principles themselves, on which men argued and acted. To accomplish this object, then,—to expose the fallacy of wrong principles,—he had to exalt the art of the dialectician to a higher function than that of merely eliciting consequences from given principles.

This attempt accordingly he made. Without instituting any formal method, or teaching any art of discourse,—without, it seems, having any such design in his thoughts,—he yet so far gave a new direction and impulse to dialectical science, as to render it in some measure at least subservient to the investigation of truth. In his hands, it served, if it did nothing more, to raise doubts as to the truth of erroneous principles which before had passed without question, and which the very practice of reasoning from them as axioms, had tended to confirm as fixed and indisputable standards of all other truths.

We must not suppose, that definition and induction were unknown as parts of dialectics before Socrates; or that Socrates was absolutely the first to discover and propound their nature and use. The expressions of Aristotle might suggest this supposition. For he says particularly, that there were two things which one might ascribe to Socrates, Definition, and Inductive Reasoning.³ What Aristotle probably intends to say, is, that Socrates was the first to improve the existing method of dialectics, by employing definition and induction as the principal engines of discussion, and illustrating their nature and use more than ever had been

¹ Xenophon speaks of the refutations employed by Socrates, serving as chastisements of presumptuous folly, *κολασηρίων ἔνεκα*. Mem. i. 4. 1.

² Nov. Org. i. 67.

³ Aristot. Metaph. xiii. 4. Δύο γὰρ ἐστὶν ἃ τις ἂν ἀποδῶη Σωκράτει δικαίως, τοὺς τ' ἐπακτικούς λόγους, καὶ τὸ ὀρίσθαι καθόλου. Ibid. i. 6. περὶ ὀρισμῶν ἐπιστήσαντος πρώτου τὴν διάνοιαν.

Socrates.

Socrates. done before him. He gave them, in fact, a body and a vitality, by applying them to the realities with which men had to do in their daily life.¹ Instead of employing them for the purpose of verbal distinction, or for the expression of some abstract and barren generality, he applied them to limit the vague notions entertained about matters of practical concern, and to bring opinions into harmony with ordinary experience. To the dialecticians before him, Definition and Induction were the commencement of their discussions. They unsuspectingly presumed on the logical processes involved in these instruments of discourse, as already sufficiently accomplished. They attempted, indeed, to define; but they took such definitions as they found at hand,—of course the most superficial.² General principles they scarcely thought of establishing; but they assumed such as were the current maxims of the day. And the rest of their discourse proceeded from these crude and unscientific elements. But Socrates did not profess to give definitions, or to have arrived at any positive certain principles, from which, as data, other truths might be demonstrated.

He disclaimed, as has been already pointed out, the design or the ability to teach. He was only an inquirer, himself *knowing nothing*. When pressed, as by the sophist Hippias, to give his own account of the particular subject about which he is importunately questioning, he evades the point, and recurs to his established way of proceeding by interrogatories.³ He is constantly, that is, endeavouring to rise to a correct definition of the subject under discussion. He presents it as the end to be attained by the whole discussion; leading the person questioned from point to point, until he brings him close to the true and exact idea of the subject. So also does he employ Induction. He cites some instance,—commonly some coarse and very familiar one, from the workshop of the smith or the shoemaker, or from the culinary art, and the like,—as apposite to the point under debate; and thus brings the principle itself, on which the dispute turns, to the test of actual experience. This was so much his manner, that it was made a standing jest by those against whom he so triumphantly employed it. They complained of his ever repeating the same thing; ever talking of “carpenters, and smiths, and fullers, and cooks, and such like nonsense.”⁴ But he was not deterred by the scoff, which in reality proved the point and force of his reasonings. He replied, that about the same things, he must persist in saying the same things; unless it could be shewn, that a person being asked, whether twice five were ten, should answer differently at different times.⁵ Thus, he would continually recur to his well-known illustrations from common life, hackneyed as they were in his own use, and low and trifling as they might seem.

From this his constant practice of bringing men to the test of definition and familiar instance, on every subject discussed, he had been regarded by the Thirty as the teacher of an “art of discourse,” and as therefore obnoxious to a law which they had made (chiefly with a view to him), forbidding the teaching of such an art.⁶ Such a restriction, however, could not apply to Socrates; since, as we have seen, he professed no art; he imparted no method of argument; and, to have silenced him, they must, as he shewed them, have absolutely prevented his asking the most simple and familiar question. Here it was the point of an apt illustration that had provoked this sally of resentment from Critias and Charicles, two of the Thirty. It had been reported to them that he had drawn attention to their acts of

violence, by asking, what would be thought of the herdsman under whose care an herd should be diminished. On this occasion, Charicles, after vainly remonstrating with him against the practice of his daily conversations, shewed the point of the illustration, by bidding him beware lest he also should make the number of the herd still less.⁷

So far, indeed, was Socrates from instituting any method either of argument or of investigation, that the very definitions and instances which he employed were of a popular character, adapted for refutation of error rather than for conviction of the truth,—such as to place difficulties in the way of a dogmatic opponent, rather than didactic illustrations of any particular subject. He was engaged in repelling dogmatism. And nothing is of more avail for this purpose than analogies; such instances, that is, as test the truth of an assumption in one case, by its application to another of the same kind. Direct instances, shewing experimentally the truth or falsehood of an assumption, may be difficult to be found; and, in their use, they require a particular acquaintance with the subject itself, in order that their application may be seen. For example, if it were desired to expose a false theory of government, some fact of history must be adduced, and its bearing on the theory in question must be distinctly pointed out. But an analogous instance does not require this intimate acquaintance with the subject itself, in illustration of which it is brought. It shews at once that a given hypothesis is either tenable, or not tenable,—that it is verified or not verified in some parallel case, and therefore may be granted or not, in the subject about which the argument is. Only it is necessary, for this purpose, that the analogous instance should be a familiar one,—that the exhibition of the principle in question should be clear and striking in the instances adduced. For example, to set forth the evil of tyranny, it would be quite enough to point out, as Socrates did, the case of a herdsman under whose keeping an herd should be deteriorated; and the inference would be immediate, that a career of confiscation and blood was no evidence of a good government. Again, whether it were wise to choose magistrates by lot, would be a difficult question to be decided by the direct evidence of facts bearing on the point. But when Socrates referred to the absurdity of appointing a steersman by lot, it was at once evident, that there were cases in which this mode of appointing important officers of the state would be mischievous. Such then was the kind of evidence which Socrates was constantly adducing from analogous instances to the point in question;—an evidence, not conveying any positive instruction in the theories of the subjects to which it was applied; but removing false impressions respecting them, and opening the mind to the reception of the truth. It was an admirable method of unteaching prejudices or vain assumptions, and of silencing the dogmatist,—a method, powerful at once for the refutation of error, and the conviction of ordinary minds incapable of being instructed by a more direct and positive evidence. Such, accordingly, was the method practised by Socrates. In pursuing any argument, “he would proceed,” as Xenophon observes, “by the most admitted principles; considering this to be the sound basis of discussion. And therefore,” adds Xenophon, “he, far beyond all I ever knew, when he spoke, carried conviction to his hearers;” and he would say, “that Homer had ascribed to Ulysses the merit of being a sound orator, on account of his ability to conduct a discussion, by reasoning from such principles as men acknowledged.”⁸

It was seldom, however, if ever, that Socrates avowedly

¹ Xenoph. Mem. iii. 3. 11. λέγεις, ἔφη, σὺ τὸν ἱππαρχὸν πρὸς τοῖς ἄλλοις ἐπιμελεῖσθαι δεῖν καὶ τοῦ λέγειν δύνασθαι; κ. τ. λ.

² Aristot. Metaph. i. 5. Καὶ περὶ τοῦ τί ἐστὶν ἤρξαντο μὲν λέγειν καὶ ὀρίζεσθαι, λίαν δ' ἀπλῶς ἐπραγματεύθησαν. ὠριζόντο τε γὰρ ἐπιπολαίως, κ. τ. λ.

³ Xenoph. Mem. iv. 4, 9.

⁴ Xenoph. Mem. iv. 4, 7. διὰ τῶν δοκούντων τοῖς ἀνθρώποις.

⁵ Xenoph. Mem. i. 2. 31. 3.—Aristid. t. ii. p. 248.

VOL. XX.

⁴ Ibid. i. 2. 37. Plato, Gorgias, p. 491, a. t. iv. p. 96.

Xenoph. Mem. i. 2. 37.

⁸ Ibid. iv. 6. 15.

Socrates. argued a point. Professing to know nothing himself, he constantly challenged others as to what they professed to know. He put his questions to each person with whom he conversed, very much as the skilful experimenter in these days does to nature, so as to lead to the affirmative or negative of a particular hypothesis whose truth he would investigate. Having obtained an answer, he proceeds analytically, to find on that another question, studiously directed, in like manner, to elicit the answer which might serve for further inquiry, and so on, until he has reduced the first proposition to some simple elements, clearly shewing the truth or falsehood of the original assumption. It was as truly an experimental process on men's minds, as that which the modern investigator performs on the subject which he examines. Those analogical instances in which he so much delighted, served the purpose of this analysis, no less than direct and proper instances, such as belong to him who investigates experimentally the nature of a particular subject. For analogies detect the state of the mind to which they are addressed. They at once call forth and illustrate its principles and habits of thought, and enable the experimenter to avail himself of the existing resources in that mind for effecting the desired conviction. They furnish him with a clue to the course which he should follow in carrying on his analysis. This was that midwifery of the mind which Socrates used sportively to describe as his peculiar occupation.

In his conversation, for example, with Euthydemus, who prided himself in having cultivated his mind by his own independent study of books, of which he had formed a large collection,—he first drew attention to the singularity of the young man's conceit, by representing him as coming before the public, with high professions of being self-taught, and putting the parallel case of a candidate for some medical office, who should announce that he had studiously avoided even the appearance of having *learned* the art of medicine, and ask for the office on the promise of endeavouring to learn the art by his future practice. Interest being excited by this illustration of the absurdity, he next led his hearers to see the absurdity of entering on political affairs without preparation, by referring to the fact of the severe application and discipline undergone by persons who seek reputation in such accomplishments as flute-playing or riding. Then, having gained over Euthydemus as a more willing listener, he proceeds to question him as to the use for which he had collected so many books. He throws out the presumption that they have been collected with a view to enrich the mind with virtue. Supposing this to be granted, he goes on to interrogate Euthydemus as to the particular excellence of which he is in quest. He enumerates several particulars; and these being rejected, he comes at last to excellence in the art of government, which the young man concedes to be the object of his desire. This gives an opening to inquire into the qualifications necessary for such excellence. He discovers, by the answers of Euthydemus, that he conceives himself master of those moral virtues which he is induced to admit are indispensable to the good citizen. By a series of questions, however, relating to particular actions, he forces Euthydemus to admit, that what is just in one case, is unjust in another, and to contradict himself in his successive statements as to the comparative criminality of voluntary and involuntary acts of injustice. What, then, triumphantly asks the philosopher, think you of a person who is so inconsistent with himself? The conclusion is inevitable; and Euthydemus is constrained to own, that "he knew not what he thought he knew." But Socrates, not yet satisfied, presses him further to explain his notion of that ignorance which he had thus displayed; and finds, that notwithstanding his confession of his want of right instruction, he yet presumes on his pos-

session of self-knowledge. Another question forces him to abandon this position. The young man then asks to be only put in the way of self-examination. Here at once his false presumptions are exposed to the searching analysis of Socrates. The inquiry turns on a knowledge of the goods and evil of life. Euthydemus enumerates one thing after another as good; and Socrates immediately subjoins some counter evil as attending it; until Euthydemus at last gives up his confidence in his own opinion, and declares that he knows not now what he ought to pray for to the gods. Again, Socrates presents before him pointedly the evidence he had thus given of having been diverted from consideration of the subject by the strong presumption of his knowledge of it. But that he may leave no room for escape, he calls on him, in conclusion, to state his opinion as to the nature of democracy, which at least, he conceived, Euthydemus, as a candidate for public office in a popular state, must have studied. And in like manner, he extorts from his successive answers a further proof of his ignorance and incompetence to the duties for which he had designed himself.

The effect thus produced is what Plato compares to the numbing touch of the torpedo.¹ The mental powers of the individual thus tried were for the moment paralyzed. He found that he only committed himself further by renewed efforts; and "began to think," as Euthydemus says of himself at the close of the conversation to which we have just referred, "whether it were not best for him to be silent, as he ran the hazard of appearing absolutely to know nothing."

From the instance just given, it will appear that a current of irony pervaded these experimental argumentations of Socrates. There was irony mingled with earnest conviction, in that very disclaimer of all knowledge with which he set out. It was a mask, behind which he could hurl his weapons of assault on the boasted knowledge of others, whilst at the same time he expressed his serious view of the real ignorance of man, and the necessity of coming with a simple unprejudiced mind to the acquisition of truth. In the prosecution, however, of his method of analysis by interrogation, irony was indispensable for the success of his inquiry. For his object was to obtain the truth from the mouth of the person interrogated, not to state it himself; and where he did state it accordingly, it was necessary to put it in such a form as to try whether it was the opinion or not of that person,—whether he really thought so, or adopted it on the judgment of his questioner. An ironical statement answers this purpose. It conceals the teacher, and enables him to judge, according as the hearer applies it, what the state of the hearer's mind is, and to argue the point in question, not on premises laid down by himself, but the admissions of the other. The hearer, too, is taken by surprise. The air of seriousness which the ironical manner sets out with, and the absurdity involved, on second thought, in carrying out the supposition of a serious intent, in their united effect, provoke the smile of surprise, and win attention. As Socrates was engaged, too, in presenting unacceptable conclusions,—bringing home to the self-conceited evidences of their real ignorance,—it was necessary for him to disguise, as much as possible, the conclusion to which he was tending. He had to assume, therefore, the principles on which those with whom he conversed were reasoning and acting, and reduce these to an absurdity, by applying them as true to some evident case of ordinary experience. The skilful use made by Socrates of this irony was a powerful enforcement, in itself, of the convictions which he desired to leave on the minds of his hearers. He brought the aid of a delicate ridicule to the support of an argument, and thus exhibited the desired conclusion under a form, which, whilst it pleased the hearers, shamed them into an acknowledgment of its truth.

¹ Plato, *Meno.*, 80 a. t. iv. p. 348.

Socrates.

But this irony, and the analogical instances over which it was thrown, were but approaches to that end which Socrates appears always to have had in view in his conversations, —the ascent to accurate general notions of each object of thought. He was always working his way towards an exact definition of the idea on which the discussion turned. Each instance which he adduced was a step in this progress, diminishing by its light some portion of that obscurity and confusion of thought with which he found the subject invested. He did not, indeed, reach the point which he had in view. Dialectical science was in too rude a state at present for the attainment of its perfect end. Socrates rather set an admirable example of the perseverance and energy with which the end should be pursued, than a perfect model of the method of pursuing it. His very method, indeed, confesses its own imperfection, in stopping just at the point where the way seems to be opened, and leaving the subject negatively, rather than positively defined.

This constant pursuit of exact definition is an indication of the antiseptical bent of the mind of Socrates. The foundations of morals and of all science were shaken by the speculations of his sophistical predecessors. Opinion was exalted to the prerogative of knowledge. Socrates accordingly put opinion to the test. He explored it experimentally, as it existed in different minds; and he proved it deficient from the standard to which it had been vainly exalted. He found that it vanished before the light of investigation; and, in fact, that in proportion as the fancies and errors of opinion were cleared away, advances were made towards more stable and certain knowledge. This knowledge, accordingly, he continually sought after. He had probably but an indistinct conception of the realities towards which he directed his pursuit. Still he appears constantly to have assumed and fully believed their existence, by steadily proceeding, as we find him to have done, through the various opinions which he encounters in discussion, until he arrives at some more definite form of thought. What Socrates only indistinctly apprehended, Plato afterwards realized in his philosophical system, and endued with existence in his celebrated theory of Ideas. But in the view of his master that theory was but dimly seen in shadow. Socrates shaped his course towards it, as he more and more limited the extravagancies of popular opinion on the various subjects which he discussed, and excluded whatever was irrelevant and foreign to the real nature of the thing. He threw doubts on what was doubtful, that there might be the less doubt and uncertainty about what remained when the doubtful was removed from a subject.

What appears to have led Socrates into this sound method of proceeding, was, as Aristotle very justly intimates, the firm moral convictions which were the great elements of his mind and character.¹ He felt that there was a reality in the principles of piety, justice, benevolence, and other moral sentiments, which no sophistry could impugn. He not only felt their reality within himself, but he had observed, that however invisible to the outward eye, they produced real effects in the world; that they were not only evidenced in the constitution of nature, but also recognized in those unwritten laws which were found everywhere the same, independently of positive institution, as well as in the enactments of particular states.² He looked for the original of these sentiments to the perfect nature of the Divinity; and he held them accordingly to be invariable and true, as the Divinity is invariable and true. Hence he

would allow no proper and adequate power of causation but moral design. Material or mechanical causes were in his view but of instrumental efficacy.³ It was moral sentiment only, the love and pursuit of good, that possessed real power. This alone, he observed, subsisted unchanged and fixed, whilst every thing else was moved by it, and derived its existence from it. It was the neglect of this primary principle in the detail of the physical theory of Anaxagoras, which had offended him in the system of that philosopher. And agreeably to this, Plato tells us of his accounting for his remaining in his prison, from the simple cause of the moral feeling by which he was actuated.

Fixing his eye accordingly on these stable eternal principles, Socrates pressed forward in every discussion towards their attainment. He would never rest in vague general classifications, which involving also much that belonged not to the subject in question, left its nature as undefined as ever. But he proceeded to a further limitation of the generalities on each subject, obliging his hearer to distinguish the subordinate genera included in the more general idea first thrown out, and thus gradually to circumscribe the subject within its proper boundaries. This was the intimate connexion of his logic and ethics. He was engaged throughout in an endeavour to remove the vain presumptions of mere opinion, and to substitute for these a real knowledge, as far as it was attainable, of the subjects themselves. He conceived that if men went astray in their conduct, acting on what they mistakenly thought right, and good, and true, it was only necessary to make them *know* the truth, and they would then act on their *knowledge*, as before they acted on mere *opinion*, and by thus acting attain their happiness. This was but a short-sighted view of the origin of human misconduct and unhappiness, as it did not go beyond the fact of the erroneous judgment of men, to the moral perversion which was the primary cause of their failure in action. As the practical error of men arises from this perversion, it is evidently vain to think to improve their conduct, by merely substituting more correct notions of truth and duty; since this remedy does not reach the source of the malady. Such, however, was the view of Socrates. And hence he laboured, whatever might be the subject of his conversations, to lead men to contemplate the nature of the thing discussed, and to seek to define it to themselves; thus blending the perception of the right and the good in the intellectual apprehension of the truth. Xenophon accordingly remarks the importance attributed by Socrates to the ability of distributing things into genera, on the ground, that by means of this talent "men would become most virtuous, most formed for command, and most able in discourse."⁴

Though Socrates thus endeavoured to render his hearers accomplished in the art of discussion, by directing their attention to Definition, he, as might be expected, in that early state of logical science, did little more than point out the great importance of Definition, and mark the direction in which it should proceed. Were we to take our estimate of what Socrates accomplished in this way from the "Dialogues" of Plato, we must suppose Socrates to have been much more methodical in his discussions, than we should infer from the specimens given by Xenophon. Something perhaps should be allowed for the practical turn of Xenophon's mind, and his comparative inattention to the more abstract part of the discussions of his master, whilst his fellow-pupil, on the other hand, who had an eagle-eye for

¹ Aristot. Metaph. i. 6. Σωκράτους δὲ περὶ μὲν τὰ ἠθικὰ πραγματευομένου, κ.τ.λ.

² Xenoph. Mem. iv. 4.

³ Aristotle gives an instance of the manner in which Anaxagoras lost sight of his theory of mind in working out his system. Anaxagoras, he tells us, said "that man was the most intelligent of animals, because he had hands; whereas he should have stated, that man had hands because he was the most intelligent of animals; for that hands were an instrument for taking hold." Aristot. de Part. Anim. iv. 10, p. 1034. Ἀναξαγόρας μὲν οὖν φησὶ, διὰ τὸ χεῖρας ἔχειν, φρονιμώτατον εἶναι τῶν ζώων τὸν ἄνθρωπον· εὐλογον δὲ, διὰ το φρονιμώτατον εἶναι τῶν ζώων, χεῖρας ἔχειν· τὸν λαμβάνειν γὰρ χεῖρες ὄργανόν εἰσιν. Ed. Duval.

⁴ Xenoph. Mem. iv. 5. 12. Ἐκ τούτου γὰρ γίγνεσθαι ἄνδρας ἀρίστους τε καὶ ἡγεμονικωτάτους καὶ διαλεκτικωτάτους.

Socrates. theory, however remote and dazzling, would seize every hint that dropped from the lips of Socrates for the indulgence of his speculative imagination. Still Xenophon may be regarded as having presented the most natural, as well as most exact, specimens of the method of Socrates. In the simplicity of his honest admiration and grateful recollection of the instructor and guide of his youth, he evidently records what had most impressed his own mind, both as to the substance and the manner of the conversations of Socrates, without any attempt either at dramatic or theoretic effect. From Xenophon we learn how Socrates appeared to the young Athenian, who, without any theories of his own, approached him, simply with the desire of hearing him, and applying what he might learn from the philosopher to his own improvement. Plato, on the other hand, whilst he also has given a faithful portrait of Socrates in the general outline, (and the faithfulness is shown by its close correspondence with that given by Xenophon,) studied to give effect, at the same time, to his own philosophic sketches, by placing the figure of Socrates in such a light as to harmonize with his own sublime and beautiful ideal of truth.

Thus we see how Socrates was the founder of the moral and logical science of the schools of Athens. He taught nothing positively in either branch of philosophy, but he taught men to inquire, and set them on the right track of inquiry. He trained men to think for themselves, to accept no opinion which should be contradicted by the moral and intellectual principles of their own nature, and to rest in no opinion until they had traced it up to these principles.

An exact logic, and a sound ethical system, would in time naturally result from such a direction of men's minds.

In giving account to themselves of their opinions, men would be led to examine into the connexions and dependencies of their ideas. Observations would be made on the relations of ideas, and of words as their signs and representatives. And such observations methodically stated, would at length constitute a system of logic, such as that which Aristotle brought to light about half a century after the death of Socrates. In the mean time, however, the value of ideas in themselves, apart from their expression by words, would engage attention; and a metaphysical logic,—a logic having for its object the determination of the true notion or idea of a thing, and for its business the discussion of the probabilities or appearances of truth surrounding the matter in question,—would naturally be the first to succeed. Such was the Dialectic of Plato,—a science of discourse or discussion, as its name imports; not a particular science, like the logic which grew out of it, but as general in its comprehension as the method itself of Socrates, of which it was the formal development, and equivalent, therefore, to philosophy in the highest sense of that term, as being a search after the nature of things, or, according to him, a theory of Ideas.

Again, in giving account to themselves of their opinions, men would be led to trace the connexion of their moral sentiments and actions with an internal standard of right, independent of the variations of opinion. The examination of this relation would suggest, in process of time, a system of rules for bringing the variable—the sentiments and actions of the individual moral agent—into accordance with the invariable principles of his moral nature. The first ethics, identical, like the first logic, with philosophy in general, would be employed in carrying the views of men to those great principles themselves,—discussing and removing obstructions to the pure contemplation of the nature of virtue. But the more mature study of ethics, taking up the subject as a separate branch of philosophy, would develop the application of the doctrine of the fixed standard, by shewing

throughout the field of man's moral nature, how every moral sentiment is strictly limited by its reference to such a standard. The former is the chief business of Plato's ethical philosophy; the latter, that of Aristotle's;—the first tending to a contemplative morality, to a love of the transcendent beauty and excellence of virtue,—the latter, to a theory of active virtue,—to a regulated state of the affections in all the offices of life;—both natural consequences in their order, of that awakening of the reason of men, of which Socrates had been the living instrument.

Socrates, at the same time, by the method which he pursued, taught men the beginning of an art of criticism. From an examination of existing opinions, the transition was natural to the systems of philosophers, and the records of the opinions of men of former days. And, in this respect, Socrates may be regarded as the father of the history of philosophy. Even had the criticism of the writings of philosophers formed no part of his conversations, still he must have prompted such an inquiry by his method of interrogating, and exacting from every one an account of his opinions. But he did more than this. Though not properly erudite, in that sense in which Plato and Aristotle were, he had yet acquainted himself with the doctrines of former philosophers. The chief part of his life was spent with his eye, not on books, but on men. Still, as we are informed by Xenophon, he had read, and had selected, in the course of his reading, whatever he thought valuable in the writings of those before him.¹ Plato, accordingly, has made great part of the conversation of Socrates consist of criticism of the theories of philosophers. Much of this criticism evidently belongs to the richly-various and elaborate learning of the disciple, rather than to the master from whose lips it proceeds. But that Plato is not gratuitously ascribing this kind of learning to Socrates, we see from the manner in which the less erudite disciple refers to the discussions by Socrates of the doctrines of former philosophers. Not only does Xenophon mention, in common with Plato, the comments of Socrates on the more recent system of Anaxagoras,² but he refers also to his examination of the great antagonist theories of the older schools, of Parmenides, Xenophanes, Melissus, and others, on the one hand; Heraclitus, Empedocles, and their followers, on the other; though without formally introducing their names.³

That various and discordant schools of philosophy should have arisen out of the excitement produced by the energetic call of Socrates to his countrymen, was in the natural course of things. Powerful minds, shaking off the yoke of sloth and indifference, and now at length roused to self-exertion, would, however generally docile to the guidance of a leader, be tempted to try their own powers, and strike out a path for themselves. We are not to wonder, then, that Aristippus, the advocate of pleasure, and Antisthenes, the austere cynic, should have been among the hearers of Socrates, or that Plato should have founded a contemplative mysticism on the sober homely philosophy of his master. Socrates, as we have all along shewn, did not propose any precise system of doctrine to his followers. His mission was accomplished in making them exert themselves. He did not desire that they should think alike, but that all should think and judge for themselves. It is no wonder, therefore, that some should have gone into extravagancies, and that, whilst general good resulted from the excitement, partial evil also should have accompanied it. An Aristippus, or an Antisthenes, could not have issued from the school of Pythagoras. But how much evil generally may have resulted from the abject submission to the authoritative opinions of Pythagoras, in the neglect of self-examina-

¹ Xenoph. Mem. i. 6. 14. Καὶ τοὺς θησαυροὺς τῶν παλαι σοφῶν ἀνδρῶν, οὓς ἐκεῖνοι κατελίπον ἐν βιβλίοις γράψαντες, ἀνελίττων κοινῇ συν τοῖς φίλοις διερχομαι, κ.τ. λ.

² Xenoph. Mem. iv. 7. ;

³ Ibid. i. 1. 1416.

Socrates. tion and self-knowledge, and disregard of personal responsibility, by those who implicitly received them?

But whilst we ascribe to Socrates the merit of having given at once the impulse and the character to Grecian philosophy, we must yet single out for special commendation, his admirable services in reviving the forgotten theory of natural religion among his countrymen. Of religion, indeed, as an external system of positive laws enforced by the state, they had, as we have before observed, more than enough. But religion, as a system of truth, was scarcely thought of. When Aristophanes¹ brings on the stage Demosthenes asking Nicias, well-known as Nicias was for his superstitious feeling; *ἐτέον ἡγέει γὰρ θεοὺς;* “really, then, do you think there are gods?”² the allusion is evidently to the real irreligion, which the most rigid and scrupulous worship of the heathen but ill concealed. Resting their belief of a Divine agency in the world on tradition and authority, men omitted to explore the witness of God in their own nature, and in the world around them. Consequently, they were exposed to every objection which the ingenuity of theory, or the folly and wickedness of the world, might suggest to their uninformed credulity, against the positive truth of their religious system. As infidelity in these days finds its refuge in the belief of an infallible church, and is itself in its turn the miserable refuge from the despotism of the very infallibility before which it crouches in silence; so among the votaries of heathen superstition, the doubts and misgivings of the thoughtful intellect, and the troubled heart, were left to prey on themselves, shut up in abject submission to an external authority, and unprepared for their own defence and support. Socrates addressed a great portion of that practical information, which, in spite of his disclaimer of the office of a teacher, he was ever imparting to all around him, to the remedy of this distempered state of the religious feelings. He saw plainly enough that the vulgar theology could not be defended on the ground of rational evidence.³ This, therefore, in his respect for the ancient laws and customs of his country, he was content to lean on the sanction of positive institution. A great reverence, he justly thought, was due to the wisdom embodied in ancient laws; and he would not encourage persons wantonly to abandon the presumptions of truth and right naturally belonging to established institutions. At least, he would not have men rashly set up their own notions against the presumptions in favour of the wisdom of other men and other days, recommended as these were by some experience of their stability and use, whilst each man’s private opinions had no such sanction, or no equivalent sanction. But he felt also, that the internal sense of religion wanted other support,—that presumptions of human vanity and corruption were, and ever would be, brought to bear against this; and that such assaults could only be repelled by a well-informed reason prepared for the encounter. He therefore provided his hearer with a solid and impregnable argument in favour of the being and providence and moral government of the Deity. The argument was what is now familiarly known as the argument from final causes, or the evidences of almighty design in the fabric and course of nature. For this purpose, he gave an induction of instances from the world without, and from the

intellectual and moral constitution of man himself, of admirable design in the adaptation of means to ends. He called upon men, with such evidences of divine benevolence around them, not to wait for any more palpable proof, such as judging from the analogy of nature they had no ground to expect, but to believe in the existence of invisible things from their effects, and from the good received to reverence the Deity its author. The language, indeed, attributed to him by Xenophon, is in remarkable correspondence with that of St. Paul, declaring, that “the invisible things of God are clearly seen, being understood by the things that are made, even his eternal power and Godhead;”⁴ and the tenor of his argument throughout illustrates the inspired observation of the apostle. More particularly we may advert to his striking inculcation of the doctrine of the moral government of God. He refers to the sense of responsibility as in itself an evidence of the existence of a Divine Power to reward and punish;⁵ and he points to the pleasure and pain, advantage and disadvantage, respectively consequent on virtuous and vicious conduct, in the course of things, as instances of a perfection of government beyond the power of human laws.⁶ The stock of instances has been enlarged by the researches of modern science, and strength has been added to them by their arrangement and combination. But Socrates, after all, has the distinguished merit of having given the argument from final causes an explicit statement and due importance in the proof of natural religion.

When we think that truths of such high import and interest were sedulously propagated for so many years in the place of concourse of the civilized world, we naturally turn from the contemplation of the living philosopher, to ask, what was the result—what was the amount of beneficial influence on the people to whom his mission was addressed. We cannot doubt, that on the whole the influence was great,—that the serious errors of many in regard to the conduct of life were corrected,—their minds opened to consider the great purposes for which they had been born into the world, and to look for happiness, not from transitory sensual enjoyments, but from the sober and vigorous exertion of their powers of thought and action. In some conspicuous instances, indeed, his endeavours strikingly failed. Critias and Alcibiades were known wherever the name of Athens was heard. And their wild and guilty career presented to the public eye a splendid mirror, from which the most unjust censure was reflected on the philosopher himself. But the many instances which must have occurred in humbler life, of his success in the work of moral reformation, are passed over in silence. That there were such instances Xenophon has given us to understand, when he observes, in his simple manner, that Socrates dismissed those who resorted to him, improved by their intercourse with him.⁷ To expect, however, any decisive and permanent public improvement from the teaching of the philosopher, would be to overlook the extent and the malignity of heathen corruption. The men of that day, as of the present, had the voice of God distinctly speaking within them, “their conscience bearing witness, and their thoughts accusing or excusing them,” according to that just description of them which Scripture has set before us. But if they

Socrates.

¹ Aristoph. Eq. 32.

² Thucyd. ii. 53, v. 105. *Ἐς τὸ θεῖον νομίσεως*,—and *ἡγούμεθα τὸ θεῖον δόξῃ*,—are expressions of Thucydides, which shew the low ground on which religion was rested in Greece.

³ Pláto, Euthyphro, p. 6. a. *Ἀλλά μοι εἰπέ πρὸς φίλιον, σὺ ὡς ἀληθῶς ἡγῇ ταῦτα γέγονεναί ὅντως;* κ.τ.λ. Op. i. 12.

⁴ Xenoph. Mem. iv. 3. 14. *Ἄ χρη κατανοοῦντα μὴ καταφρονεῖν τῶν ἀοράτων, ἀλλ’ ἐκ τῶν γιγνομένων τὴν δύναμιν αὐτῶν καταμανθάνοντα τιμᾶν τὸ δαιμόνιον.*

⁵ Ibid. i. 4. 16. *Οἷε δ’ αὖ τοὺς θεοὺς τοῖς ἀνθρώποις δόξαν ἐμφῦσαι, ὡς ἱκανοὶ εἰσιν εὖ καὶ κακῶς ποιεῖν, εἰ μὴ δυνατοὶ ᾔσαν;*

⁶ Ibid. iv. 4. 24. *Νῆ τὸν Δία, ὃ Σώκρατες, ἔφη, θείοις πάντα πάντα ἔοικε· τὸ γὰρ τοὺς νόμους αὐτοὺς τοῖς παραβαίνουσι τὰς τιμωρίας ἔχειν, βελτίονος ἢ κατ’ ἀνθρώπον νομοθέτου δοκεῖ μοι εἶναι.* So Bishop Butler, in his Analogy, part i. ch. 2, observes, “For if civil magistrates could make the sanctions of their laws take place, without interposing at all, after they had passed them, without a trial, and the formalities of an execution; if they were able to make the laws execute themselves, or every offender to execute them upon himself; we should be just in the same sense under their government then, as we are now; but in a much higher degree, and more perfect manner.” P. 51.

⁷ Xenoph. Mem. i. 2. 61. *βελτίους γὰρ ποιῶν τοὺς συγγιγνομένους ἀπέπεμπεν.* Also ib. 4. 19; iv. 5. 24.

Socrates
||
Sodor.

shut their ears, and hardened their hearts against this divine instruction, how would they listen to one who was ever upbraiding them with their dulness and inattention to its lessons and admonitions? Rather, they would feel towards him, according to that apposite illustration of Plato, as persons dozing towards one that should wake them up, and, after ridding themselves of his disturbance, think quietly to compose themselves to sleep again.¹ For he did not disguise that his mission to them was one of reproof and expostulation,—a mission, in fact, from the Deity; and that his real concern, accordingly, was not for himself, but for the success of his mission, lest they should incur the guilt of rejecting a divine gift.²

And truly we may regard that energetic call which he was ever sounding in the ears of his countrymen, as a providential warning to the heathen world of the sin and misery of the natural man, trusting to his own imaginations,—how, “changing the truth of God into a lie,” he “gives himself over unto lasciviousness, to work all uncleanness with greediness.” As God sent his prophets to his chosen people, to tell them of their transgressions, and bid them “remember the law of Moses his servant;” so in his dealings with the nations of the world, He appears to have raised up, from time to time, individuals from among themselves, heathens still, yet gifted with a purity of moral vision beyond their contemporaries, to retrace the divine outline of their fallen nature, amidst its ruins, and to declare almost authoritatively the indelible but forgotten law of right. Israel rejected its prophets; but through all the perverseness of the people, those prophets prepared the way of the Lord. The heathen world, in like

manner, refused to listen to its monitors, its legislators, and philosophers; but in spite of their general obduracy and indifference, we cannot but believe that the call was not utterly fruitless. To the original influence of Socrates especially, brought as this was to bear on the great centre of heathen civilization, it may have been in great measure owing, that the light of religious and moral truth was kept alive, however faintly burning, for successive generations, in many a dark abode of superstition; and that in a later day, the doctrine of grace and truth appealed not without effect to the Areopagite of Athens, the jailor of Philippi, and the Roman proconsul at Paphos. He certainly excited a spirit of eager curiosity on moral subjects; as was evidenced in the rise of the schools of philosophy to meet the demands of that spirit, and in the moral character of the disquisitions pursued in them. But this spirit could not have exhausted itself in mere literary discussion. There were doubtless the waverings of anxious minds beyond the precincts of the schools, to be settled; cravings after more safe direction of personal conduct than such as the world around them presented, to be satisfied. Such a state of things would keep men looking for gospel-truth. Some would feel, as Alcibiades is represented by Plato, after a conversation with Socrates, and Euthydemus by Xenophon, at a loss how to pray. And to such the answer of Socrates, as given by Plato, would very indistinctly perhaps, yet not without earnest hope, suggest the high thought, that they must wait until they could be informed by God himself, as to the proper disposition towards God and men; or until one should come to discipline them,—to remove the darkness from their eyes, and enable them to discern both good and evil.³

(J. J.)

SOCRATES was also the name of an ecclesiastical historian of the fifth century, born at Constantinople in the beginning of the reign of Theodosius: he professed the law and pleaded at the bar, whence he obtained the name of *Scholasticus*. He wrote an ecclesiastical history from the year 309, when Eusebius ended, down to the year 440; and wrote with great exactness and judgment. His work is to be found in different editions of Eusebius, Sozomenus, and the other Greek writers on the history of the church.

SODA, the name given by the French chemists to the mineral alkali, which is found native in many parts of the world.

SODERAH, a town of the province of Lahore, in the Seik territories, situated on the east side of the Chinaub, forty-eight miles N.N.W. from the city of Lahore. Long. 73. 30. E. Lat. 32. 27. N.

SODOM, formerly a town of Palestine in Asia, famous in Scripture for the wickedness of its inhabitants, and their destruction by fire from heaven on account of that wickedness. The place where it stood is now covered by the waters of the Dead Sea, or the lake Asphaltites.

SODOR, a name always conjoined with Man, in mentioning the bishop of Man's diocese. Concerning the origin and application of this word, very different opinions have been formed by the learned. Buchanan (lib. i. cap. 34.) says, that before his time the name of *Sodor* was given to a town in the isle of Man. In Gough's edition of Camden's *Britannia* (vol. iii. p. 701.) it is said, that after the isle of Man was annexed to the crown of England, this appellation was given to a small island within musket-shot of Man, in which the cathedral stands, called by the Norwegians the *Holm*, and by the inhabitants the *Peel*. In support of this opinion, a charter is quoted A. D. 1505, in which Tho-

mas earl of Derby and lord of Man, confirms to Huan Hesketh, bishop of Sodor, all the lands, &c. anciently belonging to the bishops of Man. “*Ecclesiam cathedralē sancti Germani in Holm Sodor vel Pele vocatam, ecclesiam Sancti Patricii ibidem, et locum præfatum in quo ecclesiæ præfatæ sitæ sunt.*” The truth of either, or perhaps of both, these accounts might be allowed; but neither of them is sufficient to account for the constant conjunction of Sodor and Man, in charters, registers, and histories. If Sodor was a small town or island belonging to Man, it cannot be conceived why it is always mentioned before it, or rather why it should be mentioned at all in speaking of a bishop's diocese. To speak of the bishopric of Sodor and Man in this case, would be as improper as it would be to call the bishopric of Durham the bishopric of Holy Island and Durham, or the bishopric of Darlington and Durham; the former being a small island, and the latter a town belonging to the county and diocese of Durham. Neither of these accounts, therefore, gives a satisfactory explanation of the original conjunction of Sodor and Man.

The island of Iona was the place where the bishop of the Isles resided, the cathedral church of which, it is said, was dedicated to our Saviour, in Greek *Soter*, hence *Soto-rensens*, which might be corrupted into *Sodorenses*, a name frequently given by Danish writers to the western isles of Scotland. That we may be the more disposed to accede to this Grecian etymology, the advocates for this opinion tell us, that the name *Icolumkill*, which is often applied to this island, is also of Greek extraction, being derived from *columba*, “a pigeon,” a meaning that exactly corresponds to the Celtic word *colum*, and the Hebrew word *iona*. We must confess, however, that we have very little faith in the conjectures of etymologists, and think, that upon no

¹ Plato, *Apol. Socr.* 31. a. *Op. i.* 72.

² *Ibid.* Πολλοὺ δὲ ἐγὼ ὑπὲρ εἰς αὐτοῦ ἀπολογεῖσθαι, ὥς τις αὖ οἴοιτο, ἀλλ' ὑπὲρ ὑμῶν, μὴ ἐξαμάρτητε περὶ τὴν τοῦ θεοῦ δόσιν ὑμῖν, ἐμὸν καταψηφισάμενοι. P. 71.

³ *Alcib. ii.* p. 150, d. Πότε οὖν παρέσται ὁ χρόνος οὗτος, ὃ Σωκράτης; καὶ τίς ὁ παιδεύων; ἥδιστα γὰρ ἂν μοι δοκῶ ἰδεῖν τόντον τὸν ἄνθρωπον τίς ἐστίν. Σ. Οὗτος ἐστίν ὃ μελεῖ περὶ σοῦ, κ.τ.λ. *Op. v.* p. 160.

Sodor.

Soest
||
Sofia.

occasion they alone can establish any fact, though, when concurring with facts, they certainly tend to confirm and explain them. It is only from historical facts that we can know to what the name of Sodor was applied.

It appears from the history of the Orkneys compiled by an old Islandic writer, translated and enlarged by Torfæus, that the Æbudæ, or Western isles of Scotland, were divided into two clusters, Nordureys and Sudereys. The Nordureys, which were separated from the Sudereys by the point of Ardnamurchan, a promontory in Argyleshire, consisted of Muck, Egg, Rum, Canna, Skye, Rasay, Barra, South Uist, North Uist, Benbecula, and Lewis, including Harris, with a great number of small isles. The Sudereys were, Man, Arran, Bute, Cumra, Avon, Gid, Isla, Colonsay, Jura, Scarba, Mull, Iona, Tiree, Coll, Ulva, and other small islands. All these, when joined together, and subject to the same prince, made up the kingdom of Man and the Isles. In the Norwegian language, *Suder* and *Norder* signify southern and northern, and *ey* or *ay* an island. When the Hebrides were under one monarch, the seat of empire was fixed in the Sudereys, and the Nordureys were governed by deputies: hence the former are much oftener mentioned in history than the latter; hence, too, the Sudereys often comprehend the Nordureys, as in our days Scotland is sometimes comprehended under England. Sudereys, or *Suder*, when Anglicised, became Sodor; and all the Western isles of Scotland being included in one diocese under the Norwegian princes, the bishop appointed to superintend them was called the bishop of Man and the Isles, or the bishop of Sodor and Man. Since Man was conquered by Edward III. it has been separated from the other isles, and its bishops have exercised no jurisdiction over them. Should it now be asked, why then is the bishop of Man still called the bishop of Sodor and Man? we reply, that we have been able to discover no reason; but suppose the appellation to be continued in the same way, as the title king of France was retained by the kings of Great Britain, for several centuries after the English were entirely expelled from France.

SOEST, a city of Prussian Westphalia, in the government of Minden, the capital of a circle of the same name, which extends over 240 square miles, and has a population of 33,400 persons. It is situated on the Tosterbache, and is surrounded with old and lofty walls. In 1834 it had 1200 houses in narrow and crooked streets, and 7854 inhabitants, chiefly occupied in manufactures of various kinds. Lat. 51. 34. 5. Long. 8. 0. 1. E.

SOFALA, or SEPHALA, a kingdom of Africa, lying on the east coast near Zanguebar. The name Sofala denotes, in the Hebrew and Arabic languages, *low country*. It has been celebrated by the Arabian geographers for its golden treasures, but it is from the interior that this precious metal is brought. The soil is fertile, and the climate tolerable. Numberless reefs and banks of sand render the approach dangerous. Long. 35. 40. E. Lat. 20. 20. S.

SOFFITA, or SOFFIT, in *Architecture*, any timber ceiling formed of cross beams of flying cornices, the square compartments or pannels of which are enriched with sculpture, painting, or gilding; such are those in the palaces of Italy, and in the apartments of Luxembourg at Paris.

SOFFITA, or *Soffit*, is also used for the underside or face of an architrave; and more particularly for that of the corona or larmier, which the ancients called *lacunar*, the French *plafond*, and we usually the *drip*. It is enriched with compartments of roses; and in the Doric order has eighteen drops, disposed in three ranks, six in each, placed to the right of the guttæ, at the bottom of the triglyphs.

SOFIA, a city of Turkey in Europe, the ancient Sardica. It is situated in Romelia, and is the capital of a province of its own name. It is on an extensive plain, between the two rivers Iscar and Rissava. It is surrounded

with walls flanked by towers, and defended by a citadel. It is the seat of a Greek and of a Catholic bishop; has twenty-three mosques, several Greek, Catholic, and Armenian churches, some Jewish synagogues, 8000 houses, with about 48,000 inhabitants. It is one of the most flourishing cities of the empire, depending chiefly on its manufactures. They consist of silk, woollen and linen goods, and various smaller articles. The general appearance of the town is somewhat imposing; but many of the houses are of wood, and look meanly, as there are few glass windows, and generally iron grating in their stead. Sofia was built by the emperor Justinian out of the ruins of the ancient Sardica, and fell under the power of the Turks in 1382.

SOHAGEPOOR, a town and small district of Hindustan, in the province of Gundwana. The province is situated between the 23° and 24° of N. lat. It is a barren, mountainous, and unproductive country, possessed by various savage chiefs. The town is situated eighty miles S. by E. from Rewah. Long. 81. 45. E. Lat. 23. 29. N.

SOHAM, a town of the hundred of Staplac, in the county of Cambridge, seventy-one miles from London. It is usually called Monks-Soham, to distinguish it from some villages of the same name near it, and from having been formerly the seat of a large Benedictine monastery. It has a charity school and a market on Saturday. The inhabitants were, in 1801, 2004; in 1811, 2386; in 1821, 2856; and in 1831, 3667.

SOHAUL, a town of Hindustan, province of Allahabad, thirty-five miles S.E. from Callinger. Long. 80. 52. E. Lat. 24. 40. N.

SOHNPOOR, a town of the province of Gundwana, in Hindustan, possessed by independent chiefs, situated on the Mahanuddy river, 127 miles S.E. from Ruttunpoor. Long. 83. 45. E. Lat. 20. 47. N.

SOIGNES, a city of the Netherlands, in the province of Hennegan, and arrondissement of Mons. It stands on the river Senne, which rises at the distance of about six miles. The population amounts to 4800 persons, who are chiefly employed in obtaining stone from some valuable quarries. Lat. 50. 32. Long. 3. 59. E.

SOIL, the mould covering the surface of the earth, in which vegetables grow. It serves as a support for vegetables, and as a reservoir for receiving and communicating nourishment. See AGRICULTURE.

SOISSONS, an arrondissement of the department of the Aisne in France, which extends over 480 square miles, and is divided into six cantons and 167 communes, containing 68,761 inhabitants. The capital, a city of the same name, is situated in a fine valley on the river Aisne. It has a cathedral with two towers, only one of which has been completed. The town, in 1836, contained 8124 inhabitants, employed chiefly in making linens and leather, and in spinning cotton by machinery.

SOKOR ZOK, a town of Armenia, situated about midway between Bellis and Diarbekir, and governed by a powerful prince, who rules over many different tribes of Kurds and Turcomans. Population, 6000.

SOLANDER'S ISLAND, in the South Pacific, near the south coast of New Zealand, discovered by Captain Cook in 1770. It is of a craggy surface, of great height. Long. 192. 49. W. Lat. 46. 31. S.

SOLDER, SODDER, or *Soder*, a metallic or mineral composition used in soldering or joining together other metals. Solders are made of gold, silver, copper, tin, bismuth, and lead. In the composition there must commonly be some of the metal that is to be soldered mixed with some higher and finer metals. Goldsmiths usually make four kinds of solder, viz. solder of eight, where to seven parts of silver there is one of brass or copper; solder of six, where only a sixth part is copper; solder of four,

Sohagepoor
||
Solder.

Soldier.
||
Solid.

and solder of three. It is the mixture of copper in the solder that makes raised plate come always cheaper than flat.

SOLDIER, a military man enlisted to serve a prince or state in consideration of a certain daily pay. See **ARMY**.

SOLDIN, a town of the government of Frankfurt on the Oder in Prussia. It is the capital of a circle of the same name, which extends over 404 square miles, and contains 26,600 inhabitants. The town, which is near the Soldin lake, is surrounded with walls, and contains 434 houses, with 2860 inhabitants.

SOLECISM in *Grammar*, a false manner of speaking, contrary to the rules of grammar, either in respect of declension, conjugation, or syntax. The word is Greek, *σολοικισμός*, derived from the *Soli*, a people of Attica, who being transplanted to Cilicia, lost the purity of their ancient tongue, and became ridiculous to the Athenians for the improprieties into which they fell.

SOLEURE. See **SOLOTHURN**.

SOLFA, (*Ital.*) a musical exercise for the voice when learning to sing, in which the syllables *do, re, mi, fa, sol, la, si*, are applied to their respective notes in the exercise.

SOLFAING, (*Fr. Solfier, Ital. Solfeggiare*), means the performance of such an exercise; and also the singing of a piece of music at sight with these syllables. On this subject consult the large work on singing, published for the use of the French Conservatory of Music.

SOLFATARA, a lake in the Campagna of Rome, near to Tivoli. It is of small extent, but is remarkable for containing several floating islets formed of matted sedge and herbage, with a soil of dust and sand blown from the adjacent country, and cemented by the bitumen and sulphur with which the water of the lake is impregnated. Some of these islands are more than forty feet long, and will bear five or six persons, who, by means of a pole, may move to different parts of the lake. From this lake there issues a whitish stream, emitting a sulphureous vapour, until it reaches the small river Teverone, which discharges itself into the Tiber. The water of that rivulet is of a petrifying quality, which increases in strength the farther it flows from the lake. Fish are only to be found in the Teverone before it receives this impure stream.

SOLFATERRA, a mountain of Italy in the kingdom of Naples and Terra di Lavoro. This mountain appears evidently to have been a volcano in ancient times; and the soil is yet so hot, that the workmen employed there in making alum need nothing else besides the heat of the ground for evaporating their liquids.

SOLICITOR, a person employed to take care of and manage suits depending in the courts of law or equity. There is also a great officer of the law, next to the attorney-general, who is styled the king or queen's solicitor-general; who holds his office by patent during the sovereign's pleasure, assists the attorney in managing the law business of the crown, and has fees for pleading, besides other fees arising by patents, &c. He attends on the privy-council; and the attorney-general and he were anciently reckoned among the officers of the Exchequer. They have their audience, and come within the bar in all the courts.

SOLID, in *Philosophy*, a body whose parts are so firmly connected together, as not easily to give way or slip from each other; in which sense *solid* stands opposed to *fluid*. Geometricians define a solid to be the third species of magnitude, or that which has three dimensions, viz. length, breadth, and thickness or depth. Solids are commonly divided into regular and irregular. The regular solids are those terminated by regular and equal planes, and are only five in number, viz. the tetrahedron, which consists of four equal triangles; the cube or hexahedron, of six equal squares; the octahedron, of eight equal triangles; the dodecahedron, of twelve; and the icosahedron, of twenty equal triangles. The irregular solids are almost infinite, comprehending all such as do not come under the definition of regular solids;

as the sphere, cylinder, cone, parallelogram, prism, parallelopiped, &c.

SOLIDITY, that property of matter, or body, by which it excludes all other bodies from the place which itself possesses; and as it would be absurd to suppose that two bodies could possess one and the same place at the same time, it follows, that the softest bodies are equally solid with the hardest.

Among geometricians, the solidity of a body denotes the quantity or space contained in it, and is called also its solid content. The solidity of a cube, prism, cylinder, or parallelopiped is had by multiplying its basis into its height. The solidity of a pyramid or cone is had by multiplying either the whole base into a third part of the height, or the whole height into a third part of the base.

SOLILOQUY, a reasoning or discourse which a man holds with himself; or, more properly, according to one account, it is a discourse by way of answer to a question which a man proposes to himself.

SOLIMAN II. emperor of the Turks, surnamed the *Magnificent*, was the only son of Selim I., whom he succeeded in 1520. He was educated in a manner very different from the Ottoman princes in general; for he was instructed in the maxims of politics and the secrets of government. He began his reign by restoring those persons their possessions whom his father had unjustly plundered. He re-established the authority of the tribunals, which was almost annihilated, and bestowed the government of provinces upon none but persons of wealth and probity. "I would have my viceroys," he used to say, "resemble those rivers that fertilize the field through which they pass, not those torrents which sweep every thing before them." After concluding a truce with Ishmael Sophy of Persia, and subduing Gozeli Bey, who had raised a rebellion in Syria, he turned his arms against Europe. Belgrade was taken in 1522, and Rhodes fell into his hands the year following, after an obstinate and enthusiastic defence. In 1526 he defeated and slew the king of Hungary in the famous battle of Mohatz. Three years afterwards he conquered Buda, and immediately laid siege to Vienna; but after continuing twenty days before that city, and assaulting it twenty times, he was obliged to retreat with the loss of 80,000 men. Some time after he was defeated by the Persians, and disappointed in his hopes of taking Malta. He succeeded, however, in dispossessing the Genoese of Chio, an island which had belonged to that republic for more than two hundred years. He died at the age of seventy-six, while he was besieging Sigeth, a town in Hungary, on the 30th August 1566.

SOLINGEN, a town of the Prussian government of Cleves, the capital of a circle of the same name. It has been long celebrated for the excellent temper of the sword blades and other cutting instruments fabricated in the town and district. The circle is small, including only forty-two square miles, but it contains 28,500 inhabitants, of whom about four thousand reside within the town. Lat. 51. 12. 31. Long. 7. 2. 20. E.

SOLIS, ANTONIO DE, a Spanish writer, of an ancient and illustrious family, was born at Placentia, in Old Castile, on the 18th of July 1610. He was intended for the law; but his inclination toward poetry prevailed, and he cultivated it with great success. Philip IV. of Spain made him one of his secretaries; and after the king's death, the queen-regent appointed him historiographer of the Indies, a place of great profit and honour. His history of the conquest of Mexico, shows that she could not have named a fitter person. "*Historia de la Conquista de Mexico*." Madrid, 1684, fol. He is better known by this history, than by his poetry and dramatic writings, though in these he was also distinguished. At the age of fifty-six he took orders. He died at Madrid on the 19th of April 1686.

Solidity.
||
Solis.

Solitaires.
||
Solon.

SOLITARIES, a denomination of nuns of St. Peter of Alcantara, instituted in 1676. The design of the institution was to imitate the severe penitent life of that saint. Thus they were to keep a continual silence; never to open their mouths to a stranger; to employ their time wholly in spiritual exercises, and leave their temporal concerns to a number of maids, who had a particular superior in a separate part of the monastery. They were always to go barefooted, without sandals; gird themselves with a thick cord, and wear no linen.

SOLITARY ISLAND, in the South Pacific ocean, discovered by Mendana in 1595. It is low, and surrounded with rocks. Long. 178. 20. W. Lat. 10. 4. S.

SOLITARY ISLANDS, a cluster of small islands near the east coast of New Holland. Lat. 30. 8. S.

SOLO, or **SAURA-CORTA**, an inland town of Java, the capital of a district, and the residence of an emperor. It is large and populous, intersected with broad and shaded avenues or streets, running at right angles. The emperor's palace is very spacious, and comprises several palaces in its area. The European town and port are very neat. The resident's house is also a large and handsome building. A fine river, which flows near the town, and falls into the harbour of Grepie, affords in the rainy season a ready conveyance for the various productions of a large tract of country, in exchange for commodities which are sent up in boats from the coast.

SOLO, (*Ital.*) a term used in musical compositions of several parts, to mark those voices or instruments that are to perform alone or in a more prominent manner; as, *sofrano solo*, *violino solo*, &c. The plural is used when two or more voices or instruments of the same name are to perform alone. *Solo* is also a name given to a composition written for a single instrument, such as a violin, an oboe, a flute, &c., which is accompanied by a bass for the violoncello, or a thorough-bass for the pianoforte.

SOLOFRA, a city of Italy, in the Neapolitan province Ulteriore. It contains three churches and 6050 inhabitants, who are manufacturers of gold and silver articles, of leather and parchment, and are celebrated for their salted hams and bacon.

SOLLER, a town in Majorca, one of the Balearic islands in the Mediterranean, belonging to Spain. The valley in which it stands is productive of olives and oranges. It is situated in Lat. 39. 61., and contains 5614 inhabitants.

SOLOMBO, **GREAT**, a small island in the Eastern seas, of a moderate height. Long. 114. 45. E. Lat. 5. 36. S. Little Solombo is near the north-east coast of Great Solombo.

SOLOMON, the son of David king of Israel, renowned in Scripture for his wisdom, riches, and magnificent temple and other buildings. Towards the end of his life he sullied his former glory by his apostacy from God; from which cause vengeance was denounced against his house and nation. He died about 977 B.C.

SOLOMON'S ISLANDS. This group is in the South Pacific ocean, situated chiefly between long. 155° and 160° E. lat. 5° and 12° S. Little is known of the precise situation or number of these islands. The longest are Ysabel, Guadalcanar, San Cristoval, and an island called New Georgia. The first two are affirmed by the Spaniards to be very large islands; the latter nearly seventy miles in extent. Georgia is still larger, and San Cristoval is not less than sixty. These islands were discovered in 1567.

SOLOMON, one of the seven wise men of Greece, was born at Salamis, of Athenian parents, who were descended from Codrus. His father leaving little patrimony, he had recourse to merchandise for his subsistence. He had, however, a greater thirst after knowledge and fame than after riches, and made his mercantile voyages subservient to the increase of his intellectual treasures. He very early culti-

vated the art of poetry, and applied himself to the study of moral and civil wisdom. When the Athenians, tired out with a long and troublesome war with the Megarensians, for the recovery of the isle of Salamis, prohibited any one, under pain of death, to propose the renewal of their claim to that island, Solon thinking the prohibition dishonourable to the state, and finding many of the younger citizens desirous to revive the war, feigned himself mad, and took care to have the report of his insanity spread through the city. In the mean time he composed an elegy adapted to the state of public affairs, and committed it to memory. Every thing being thus prepared, he sallied forth into the market-place with the kind of cap on his head which was commonly worn by sick persons, and ascending the herald's stand, he delivered, to a numerous crowd, his lamentation for the desertion of Salamis. The verses were heard with general applause; Pisistratus seconded his advice, and urged the people to renew the war. The decree was immediately repealed; the claim to Salamis was resumed; and the conduct of the war was committed to Solon and Pisistratus, who by means of a stratagem defeated the Megarensians and recovered the island.

His popularity was extended through Greece in consequence of a successful alliance which he formed among the states in defence of the temple at Delphi against the Cirrhæans. When dissensions had arisen at Athens between the rich creditors and their poor debtors, Solon was created archon, with the united power of supreme legislator and magistrate. He soon restored harmony between the rich and poor. He cancelled the debts which had proved the occasion of so much oppression; and ordained that in future no creditor should be allowed to seize the body of the debtor for his security. He made a new distribution of the people, instituted new courts of judicature, and framed a judicious code of laws, which afterwards became the basis of the laws of the twelve Tables in Rome. Among his criminal laws are many wise and excellent regulations; but the code is necessarily defective with respect to those principles which must be derived from the knowledge of the true God, and of pure morality, as the certain foundations of national happiness. Two of them in particular were very exceptionable; the permission of a voluntary exile to persons that had been guilty of premeditated murder, and the appointment of a less severe punishment for a rape than for seduction. Those who wish to see accurately stated the comparative excellence of the laws of Moses, of Lycurgus, and Solon, may consult the prize Dissertations relative to natural and revealed religion, published by the Teylerian Society of Haarlem, vol. ix.

The interview which Solon is said to have had with Cræsus king of Lydia; the solid remarks of the sage after surveying the monarch's wealth; the recollection of those remarks by Cræsus when doomed to die, and the noble conduct of Cyrus on that occasion, are known to every school-boy. Solon died in the island of Cyprus at a very advanced age. Statues were erected to his memory both at Athens and in Salamis. His thirst after knowledge continued to the last: "I grow old," said he, "learning many things." Among the apophthegms and precepts which have been ascribed to Solon, are the following: Laws are like cobwebs, that entangle the weak, but are broken by the strong. He who has learned to obey, will know how to command. In all things let reason be your guide. Diligently contemplate excellent things. In every thing that you do, consider the end.

The chronology of his life is involved in no small obscurity. His legislation may, with some degree of confidence, be referred to the year 594 before Christ; but, as a very learned and able chronologer has remarked, since both his age and the time of his death are doubtful, nothing can be with certainty affirmed of the year of his

Solon.

Soloon.
||
Solstice.

birth.¹ According to Laertius, he died at the age of eighty; but Lucian extends his life to one hundred years. Of the poems of Solon, an elaborate edition has recently been published by Bach, under the title of "Solonis Atheniensis Carminum quæ supersunt." Bonnæ, 1825, 8vo.

SOLOON, a small island in the Eastern seas, twenty-five miles from the island of Samar. Long. 125. 42. E. Lat. 10. 55. N.

SOLOR ISLE, an island in the Eastern seas, separated from the island of Floris by the straits of Floris. It is about thirty miles in length, by fifteen in average breadth.

SOLOTHURN, a canton of Switzerland. It is bounded on the north by France and by Basel, on the east by Basel and Zurich, and on the south and west by Berne. It extends over two hundred and fifty-eight square miles, comprising two cities, one market-town, and one hundred and thirty-seven villages, with 59,122 inhabitants, of whom 54,000 are catholics, and the remainder protestants. The revenues amount to 180,000 francs, and the yearly expenditure to 164,000. It is bound to contribute 904 men, and 1365 francs to the general confederation. The mountains are a continuation of the Jura range, and none of them exceeds 3900 feet in height. The river Aar receives the smaller streams. There are no extensive lakes. The climate is temperate, and the soil produces good corn, hemp, flax, fruit, and wine. The chief employment is agriculture and cutting the extensive woods, which supply some fuel and building timber for exportation.

SOLOTHURN, a city of Switzerland, the capital of the canton of that name. It stands at the foot of the Jura mountains, on both sides of the river Aar. It is surrounded with walls and defended by bastions, is well, but irregularly built, and contains 560 houses, with 4470 inhabitants. It has a college with five professors and a good public library. Solothurn contains several manufactories for making and printing cotton, and some other goods. Lat. 47. 12. Long. 7. 26. E.

SOLOTONOSCHA, a town of Russia, the capital of a circle of the same name, in the province of Pultowa, 947 miles from Petersburg. It stands at the point where the Solontschia falls into the Dneiper. It contains three churches, two monasteries, eight hundred houses, and 5650 inhabitants, chiefly employed in agriculture. Lat. 49. 58. Long. 31. 58. E.

SOLSTICE, in *Astronomy*, the time when the sun is in one of the solstitial points; that is, when he is at his greatest distance from the equator; thus called because he then appears to stand still, and not to change his distance from the equator for some time; an appearance owing to the obliquity of our sphere, and to which those living under the equator are strangers.

The solstices are two in each year; the æstival or summer solstice, and the hyemal or winter solstice. The summer solstice is when the sun seems to describe the tropic of cancer, which is on June 22, when he makes the longest day: the winter solstice is when the sun enters the first degree, or seems to describe the tropic of capricorn, which is on December 22, when he makes the shortest day. This is to be understood as in our northern hemisphere; for in the southern, the sun's entrance into capricorn makes the summer solstice, and that into cancer the winter solstice. The two points of the ecliptic, at which the sun's greatest ascent above the equator, and his descent below it, are terminated, are called the *solstitial points*; and a circle, supposed to pass through the poles of the world and these points, is called the *solstitial colure*. The summer solstitial point is in the beginning of the first degree of cancer, and is called the *æstival* or *summer point*; and the winter solstitial point is in the beginning of the first

degree of capricorn, and is called the *winter point*. These Solymania, two points are diametrically opposite to each other.

SOLYMANIA, called also Shehr Zaur, a town of Kurdistan, the residence of the Pacha. The town had fallen into decay, but was rebuilt by Solyman the Pacha, who, in 1810, having taken up arms against the Pacha of Bagdad, defeated him and put him to death. Population, 6000; fifty-four miles east of Kerkook.

SOMALPET, a town of Hindustan in the Nizam's province of Nandere, fifty-two miles N.N.E. from the town of Nandere.

SOMBOR, or ZOMBOR, a city of the kingdom of Hungary, in the province of the hither Danube, in the circle of Kozep Jaras. It contains 2980 houses, with 14,860 inhabitants, whose chief trade is in corn and cattle. Lat. 48. 8. 32. Long. 21. 10. 33. E.

SOMERS, JOHN Lord, high chancellor of England, was born at Worcester in 1652. He was educated at Oxford, and afterwards entered himself at the Middle-Temple, where he studied the law with great vigour. In 1688 he was one of the counsel for the seven bishops at their trial, and argued with great learning and eloquence against the dispensing power. In the convention which met by the prince of Orange's summons, January 22, 1689, he represented Worcester; and was one of the managers for the House of Commons, at a conference with the House of Lords upon the word *abdicated*. Soon after the accession of William and Mary to the throne, he was appointed solicitor-general, and received the honour of knighthood. In 1692 he was made attorney-general, and in 1693 advanced to the post of lord-keeper of the great seal of England. In 1695 he proposed an expedient to prevent the practice of clipping the coin. In 1697 he was created Lord Somers, baron of Evesham, and made lord high chancellor of England. In the beginning of 1700 he was removed from his post of lord chancellor, and the year after was impeached of high crimes and misdemeanours by the House of Commons, of which he was acquitted upon trial by the House of Lords. He then retired to a studious course of life, and was chosen president of the Royal Society. In 1706 he proposed a bill for the regulation of the law; and the same year was one of the principal managers for the union between England and Scotland. In 1708 he was made lord president of the council; from which post he was removed in 1710, upon the change of the ministry. In the latter end of Queen Anne's reign his lordship grew very infirm in his health; which is supposed to be the reason that he held no other post than a seat at the council-table, after the accession of King George I. He died of an apoplectic fit in 1716. Mr. Addison has drawn his character very beautifully in the Freeholder.

SOMERSETSHIRE, a maritime county of England, lying in a crescent-like form on the Bristol Channel, to which its north-western side is turned. It is bounded to the north-east by Gloucestershire, on the east by Wiltshire, on the south by Dorsetshire and part of Devonshire, and on the west by the latter county. Its greatest length, from east to west, is sixty-five miles, and its greatest breadth, from north to south, forty-five miles. Its boundary line has several considerable indentations. The whole area comprehends 1642 square statute miles, or 1,050,880 English acres; being in extent the seventh in the list of the English counties. The acreable value of the land, according to the late returns under the property-tax, exceeded that of any other county except Leicestershire, being, including the tithes, L.876 per square mile, or about 27s. per acre.

The civil divisions of this county are denominated the eastern and the western. The eastern division contains

Solymania,
||
Somer-
shire.

¹ Clinton's *Fasti Hellenici*, vol. ii. p. 301.

Somerset-shire. twenty hundreds and seven liberties, and the western twenty-two hundreds; but these divisions have become of less importance, since other divisions have been politically framed by the Reform act, as will be hereafter noticed. The whole county is in the diocese of Bath and Wells; and is ecclesiastically divided into three archdeaconries, under which are thirteen deans, who superintend 482 parishes. There are within the county two cities (besides a part of Bristol), seven boroughs sending members to Parliament, and twenty-nine market towns.

The population of this county at the four decennial periods of enumeration, has been found to be as follows: In 1801, 273,750; in 1811, 303,180; in 1821, 355,314; and in 1831, 402,500.

In 1831, the occupiers of land employing labourers were.....	6,032
The occupiers of land not employing labourers...	3,731
Labourers employed in agriculture.....	28,107
Labourers in manufactures.....	4,350
Labourers employed in retail trade or handicraft,	26,672
Capitalists, bankers, &c.....	4,676
Labourers not agricultural.....	12,183
Other labourers under twenty years of age.....	7,074
Males at and above twenty years of age.....	95,556
Male servants.....	2,801
Female servants.....	18,333

In the same year the number of families chiefly employed in agriculture was found to be 30,452; of those chiefly employed in trade, manufactures, and handicraft, 20,230, and of those not comprised in either of the preceding classes, 25,889. The number of inhabited houses was 71,325, occupied by 84,571 families; the uninhabited houses, 3,632, and those building, 939. The annual value of the real property of the county, as assessed in 1813, was L.1,900,651.

The towns whose population in 1831 exceeded 2000, were as follows:

Bath.....	38,063	North Petherton.....	3,566
Bedminster, a sub- urb of Bristol.....	13,130	Wedmore.....	3,557
Frome Selwood.....	12,240	Wivelscombe.....	3,047
Taunton.....	11,139	Ilminster.....	2,957
Bridgewater.....	7,807	Martoch.....	2,841
Wells.....	6,649	Glastonbury.....	2,500
Yeovil.....	5,921	Twerton, sub. of Bath..	2,478
Shepton-Mallet.....	5,330	South Petherton.....	2,294
Chard.....	5,141	Milverton.....	2,233
Wellington.....	4,762	Keynsham.....	2,142
Bathwick, a sub- urb of Bath.....	4,033	Wincanton.....	2,123
Crewkerne.....	3,789	Nailsea.....	2,114
		Milbourn Port.....	2,072
		Bruton.....	2,031

Few districts contain a greater variety of soil and situation than the county of Somerset. In the north-east corner, the range of the Mendip hills presents a lofty tract of country, of late improved on the surface, but chiefly valuable for the coal and other mines beneath it. On the western side are the Quantock hills, an extensive and sterile range, and beyond them the elevated bleak plain called the forest of Exmoor, the highest district in the western counties. One spot in this forest, called Dunkeny, is 1668 feet above the level of the sea; and from it a prospect over an extended and diversified country is displayed, terminating on one side in the Bristol, and on the other in the English Channel. These hilly, and somewhat barren portions of the county, however, bear but a small proportion to the whole; and between them are to be seen the richest meadows and arable lands, the value of which more than counterbalances the sterility of the hills. In the better parts of the county, it may rather be described as rich than beautiful. There is a deficiency of woods; the

streams that run in the valleys are sluggish, and in summer nearly stagnant; but the extent of orchards, especially when in full bloom, produces a pleasing effect, and in some measure compensates for the want of woods.

The rivers of the county are the Avon, which enters it from Wiltshire, and becomes navigable at Bath, which city it nearly surrounds. It then passes, with many curvatures, to Bristol, and soon after is lost in the Severn. The Axe rises in the Mendip hills in two branches, one of which issues from a natural excavation, called Wookey Hole, resembling some of the Derbyshire caverns. Its course is short, and it empties itself through some marshes, below Axbridge, into the Bristol Channel. The Brue rises in Wiltshire, and also enters the Bristol Channel, being navigable not more than two miles from its mouth. The Parret rises at a village of the same name in Dorsetshire, becomes navigable at Langport, and in rainy seasons a few miles above that town. It is joined, at Boroughbridge, by the Thone or Tone, which proceeds from Taunton, and passing by Bridgewater, empties itself into the sea. The only navigable canal that has been completed is the Kennet and Avon, which unites together the two great rivers Thames and Severn. It commences near Bath, and soon enters Wiltshire. Other canals have been projected in different directions, but none of them has been prosecuted to completion; though on several of them large sums have been expended.

As Somersetshire contains, on the banks of its rivers, large tracts of the richest meadow lands, the most valuable branch of its rural economy is the fattening of cattle and the management of the numerous dairies. The oxen, bred chiefly in the less fertile pastures of Devonshire, when grazed in this county, afford the best beef, and furnish, in great numbers, the markets of the metropolis, as well as those of Bristol and Bath, in their immediate vicinity. The produce of the dairy is of the best kind. The cheese of Cheddar has obtained great celebrity, but that made in many other parts, and frequently sold as Gloucester, is equal to any in the world. The butter in the southern division of the county is excellent, and much of it, collected in the vicinity of Crewkerne, is sent to the London cheese-mongers, who supply it to their customers under the denomination of Dorsetshire butter.

The next agricultural product is cider, which forms almost the universal beverage of the working classes. It is a more pure and yet a stronger liquor than the cider either of Herefordshire or Devonshire. The consumption of it within the county is very large, and some is sent to distant parts. Nature has been so bountiful in furnishing spontaneous productions, that to those agricultural pursuits which depend on skill and industry less attention is paid in this than in many other districts. Such is the abundance of natural grass, that the farmers do not find it necessary to grow a crop of clover, or other artificial grass, so uniformly between two corn crops as is necessary in other counties; nor is the practice of fallowing, or of introducing a rotation by commencing with turnips, much resorted to. Notwithstanding this, they grow good crops of corn, and in the hundred of Taunton Dean the wheat is of the very best quality. Barley is not very extensively cultivated, as the general use of cider causes but little consumption of malt. The barley crops are in general very good. Oats are extensively cultivated, but scarcely equal the demands of the county, and the easy intercourse with Ireland readily supplies any deficiency when it occurs. The soil is well calculated for the growth of flax, and it furnishes a large proportion of that used in the manufactures of the county. It is not unusual to rent land for half a year while a crop of flax is raised; after which it is taken again by the regular occupant, who finds the flax to be an excellent preparative for wheat, from the careful weeding necessary to its growth.

Somerset-
shire.

The rich loamy soil brings to maturity the best elm timber. Goose feathers were formerly produced in great abundance; but the draining and inclosing many of the richest marshy plains has rendered these capable of yielding more profit by other productions, and of late years the quantity of feathers is much diminished. The landed property of the county is much divided, no one proprietor or great family having such extensive possessions as to give a preponderant political influence. There is a great number of yeomen who share the lands, and many of them maintain the homely independence of the past generations.

The mineral products of this county are valuable. The hills of Mendip supply with coals their vicinity, the cities of Bath and Wells, and the towns of Frome and Shepton-Mallet. The other parts of the county use the coals of Newport, which are brought by sea to Bridgewater. Lead, of a quality superior to that of Derbyshire, is found in Mendip and on the Cheddar hills. Calamine is extensively produced, and supplies the brass manufacturers of Bristol. Copper is found near Stowey. Manganese, bole, and red ochre, are among the other products of Mendip.

This is a manufacturing district for various productions. The manufacture of fine woollen cloth is extensive, chiefly at Frome, where it employs 730 males upwards of twenty years of age; and at Road are employed 59, at Beckington 32, Charter Henton, 24, Twerton, near Bath, 284, Lyncombe and Wedcombe, 565, and at Freshford, 32 makers of fine cloths. In another part of the county, at Wellington and Milverton, are nearly 300 makers of cloth of an inferior description. About 300 men are employed in making sail-cloth, sacking, and girth-web, at Crewkerne and the parishes of East Coker, Merriot, West Hatch, and North Perrot. At Chard 478 men, and at Ilminster 21, are occupied in making silk and lace, or the machinery for those fabrics; and the same trades afford considerable occupation at Bruton and Taunton. At Yeovil, and some of the towns and villages near it, the chief trade is glove-making, which gives employment to more than 600 men, and a great number of females. Edge tools are made at Wells, employing 60 men, and also at Whately, Emborrow, and some other places. At Nailsea, 100 men are employed in the manufacture of glass; paper-making and tanning occupy 59 men at Cheddar; and at various places in the county are noticed manufactures of iron, calamine, copper, brass, paper, and snuff; and a variety of small articles is made at Bath.

The foreign commerce of Somersetshire passes chiefly through Bristol, which is the mart for such goods as are required in distant countries. Some of the woollen goods which are manufactured at Taunton and Wellington are shipped from Exeter. The far greater portion of the productions of the county are, however, destined to supply the demand for internal consumption. The cattle, butter, and cheese, are chiefly sent to London, and in time of war, to Portsmouth and Plymouth. The linen and woollen goods are distributed through the western and Welsh counties, and, in general, are destined more for the home than for foreign markets.

The titles derived from this county are those of the dukes of Somerset and Wellington; the marquises of Lansdowne, Bath, and Bristol; the earls of Bridgewater, Poulet, and Ilchester; and the barons Mendip and Glastonbury. By the reform bill the county has been politically formed into two divisions, the eastern and the western, and each division elects two members to the house of commons. The election for the first is held at Wells; and the other polling places are Bath, Shepton-Mallet, Bedminster, Axbridge, and Wincanton. The election for the second is held at Taunton; and the other polling places are Bridgewater, Ilchester, Williton, and Langport.

The seats of the nobility and gentry, especially of the latter, near Bath and Bristol, are numerous; and our limits

allow only of noticing the most distinguished of them, viz. Somerton. Longleat, the seat of the Marquis of Bath; Hinton, the seat of Earl Poulet; and the houses of the Earl of Carnarvon, Lord Hood, Mr. Miles, and Colonel Gore Langton. || Somnambulism.

Two members are chosen for each of the cities of Bath and Wells, and two for each of the boroughs, Taunton and Bridgewater. The boroughs of Minehead, Ilchester, and Milburn-Port, which chose two members each, have been disfranchised, and the town of Frome has been made a parliamentary borough, returning one member. Ilchester, from the elections being held there, and from its containing the gaol and county court, is usually considered the county town, although the assizes in the spring are held at Taunton, and in the summer at Wells and Bridgewater alternately.

SOMERTON, a town in the hundred of that name in the county of Somerset, 125 miles from London. It is pleasantly situated in a fertile country. The inhabitants were in 1801, 1145; in 1811, 1478; in 1821, 1643; and in 1831, 1786.

SOMMEANY, a town of Persia, in the province of Mekram, and the principal sea-port of Lus. It is situated on an elevated bank, at the mouth of the river Pooralee, which forms a bar about a mile from the town, with three fathoms depth at low water, and boats can anchor close to the shore. It is an inconsiderable place, and the inhabitants, with the exception of a few Hindu merchants, subsist by fishing.

SOMMEE, a town of Hindustan, in the province of Gujrat. It is a large place, but has a wretched appearance, and the wall by which it is surrounded is in many parts falling to pieces. It stands in a swamp, and is surrounded by numerous puddles, and in the rainy season is almost under water. It is situated to the south-east of Rahdunpoor.

SOMME, a department of the north of France. It has been formed out of those parts of the ancient Picardy known as Amienois, Ponthieu, Vimieux, and Santerre, and extends over 614,287 hectares, or 2399 square miles. It is bounded on the north by the Pas de Calais; on the east by the departments of the North and of the Aisne; on the south by the Oise and the Lower Seine; and on the west by the British channel. It contains five arrondissements, with forty-one cantons, and 835 communes, and its population in 1836 amounted to 552,706. The surface is flat and level, but gradually slopes towards the sea on the western side. There are no mountains, but some hills of inconsiderable height rise on the eastern frontier. The Somme, which has its source in the department of the Aisne, is the chief river. The others are the Avre, the Noye, the Celle, and the Brisle. The soil is chalky, and naturally fruitful. The inhabitants cultivate to a great extent corn and hemp, and considerable quantities of corn are exported. Cattle and sheep are reared in large flocks. The country is almost destitute of wood, but the valleys abound in peat. The wine produced is small in quantity, and inferior in quality. Oleaginous seeds are extensively cultivated for the manufacture of oil. In this district are numerous and extensive establishments for the manufacture of woollen cloths and fine linen goods, such as cambrics, lenos, and lawns, carpets, hats, hosiery, leather, soap, cutlery, and other hardware. It is, on the whole, one of the most prosperous divisions of the kingdom, and contains, besides many towns and villages densely inhabited, the large cities Amiens (population, 46,129) and Abbeville, (population, 18,247), in which most of the commerce of the department is concentrated.

SOMNAMBULISM, or SLEEP-WALKING. According to a report made to the Physical Society of Lausanne, by a committee appointed to examine a young man who was accustomed to walk in his sleep, the disposition to this singular habit seems to depend on a particular affection of the nerves, which both seizes and quits the patient during

Somnam-
bulism.

sleep. Under the influence of this affection, the imagination represents to him the objects which strike him while awake, with as much force as if they really affected his senses; but it does not make him perceive any of those which are actually presented to his senses, except in so far as they are connected with the dreams which engross him at the time.

If during this state the imagination has no determined purpose, he receives the impression of objects as if he were awake; only, however, when the imagination is excited to lend its attention towards them. The perceptions obtained in this state are very accurate; and when once received, the imagination renews them occasionally with as much force as if they were again acquired by means of the senses. But the impressions received during this state of the senses disappear entirely when the person awakes, and do not return till the return of the same disposition in the nervous system.

The remarks of this committee were made on a lad named Devaud, who was thirteen years and a half old, and who lived in the town of Vevey. He possessed a robust constitution; but his nervous system appeared to be organized with peculiar delicacy, and to discover marks of the greatest sensibility and irritability. His senses of smell, taste, and touch, were exquisite: he was subject to fits of immoderate and involuntary laughter; and he sometimes wept without any apparent cause. His sleep was at all times unquiet, but particularly when the fits were about to seize him. During his sleep, motions were observable in every part of his body, with starting and palpitations; he uttered broken words, sometimes sat up in his bed and lay down again. He then began to pronounce words more distinctly, and rising abruptly, acted as he was instigated by the dream which then possessed him.

From the facts which were brought under the observation of this committee, they inferred that the functions of the somnambulist, while under the influence of this affection, are not suspended, as to what he wishes to see, or the objects about which his imagination is occupied; that he may also be disposed to receive those impressions when his imagination has no other object at the time; that in order to see, he is obliged to open his eyes as much as he can, but when the impression is once made it remains; that objects may strike his sight without striking his imagination, if it is not interested in them; and that he is sometimes informed of the presence of objects without either seeing or touching them.

A great number of similar instances might very easily be accumulated. Such anomalous operations of the mind it is perhaps beyond the power of philosophy to explain; but a very small portion of philosophy, or even common sense, will enable us to dispose of another class of vagaries imputed to animal magnetism. The magnetisers are a sort of conjurers, who, according to their own account, are able to superinduce a state of sleep, and, while their patients are in that state, to exercise a marvellous influence over their volitions. Deleuze, in his *Histoire Critique du Magnétisme Animal*, furnishes these very edifying details: "When magnetism produces somnambulism, the being who finds himself in this state acquires a prodigious extension in the sense of feeling. Several of his exterior organs, usually those of sight and hearing, are rendered torpid, and all the sensations which depend on them are internally performed. There is in this state an infinite number of shades and varieties; but in order to form a correct judgment, it must be examined in its greatest remoteness from the state of waking, passing over in silence every thing that experience has not established. The somnambulist has his eyes closed, and does not see by the eyes nor hear by the ears; but he sees and hears better than a waking man. He sees and hears only those with whom he is in relation. He sees only that which he looks at, and he usually looks only at those objects

to which his attention is directed. He is subject to the will of his magnetiser for every thing that cannot harm him, and for every thing that is not opposed to his ideas of justice and truth. He feels the will of his magnetiser; he perceives the magnetic fluid; he sees, or rather he feels, the interior of his own body, and those of others; but he usually remarks only the parts which are not in the natural state, and which disturb the harmony of the economy; he retraces in his memory the remembrance of things which he had forgotten while awake; he has pre-visions and pre-sensations, which may be erroneous in several circumstances, and which are limited in their extent; he expresses himself with a surprising facility; he is not exempt from vanity; he improves of himself, for a certain length of time, if he is wisely managed; he spoils if he is ill directed. When he re-enters into the natural state, he absolutely loses the recollection of all sensations, and of all ideas which he has had in the state of somnambulism; so that these two states are as unconnected with one another, as if the somnambulist and the waking man were two different beings." The simple enunciation of such absurdities as these, seems to preclude the necessity of all formal discussion.

In addition to their other attributes, some of the magnetic somnambulists are endowed with a miraculous skill in physic. "Those patients in crisis," says Cloquet, "who are named physicians, have a supernatural power, by which, on touching a patient who is presented to them, on carrying the hand even above the clothes, they feel what is the affected organ, the suffering part; they declare it, and mention nearly the suitable remedies. A singularity not less remarkable than all those which I have enumerated is, that those physicians who for several hours have touched patients, and have reasoned with them, remember nothing, absolutely nothing, when the master pleases to disenchant them, and to restore them to their natural state. The time which has elapsed from their entrance into the crisis to their coming out of it, is, so to speak, annihilated to such a degree, that if a covered table be presented to these sleeping physicians, they will eat and drink; and if, the table being uncovered, the master restores them to their natural state, they will have no recollection of having done so. The master has the power not only, as I have already said, to make himself be understood by these physicians in crisis, but I have repeatedly seen him present from a distance his finger to one of these physicians, always in crisis, and in a state of spasmodic sleep, make him to follow him where he pleased, or send him to a distance from himself, either to his house or to different places, which he mentally indicated without telling him."

Another phenomenon, equally worthy of admiration, is the power of reading without the aid of eyes. Pigeaire, a physician of Montpellier, is answerable for the following statement of his daughter's performances in this new department. "We made her read with her eyes closed by magnetic sleep, or covered with a handkerchief in the form of a bandage; she read with the greatest facility characters printed or written, not only in applying her fingers to the paper, but also with a plate of glass interposed between the book and her fingers. More than forty persons have been witnesses of this experiment, which we took care to perform before only a few persons at a time, in order not to disturb the little somnambulist. This experiment has never failed; once only it has been incomplete. The little girl, in the state of somnambulism, named certain objects enclosed in snuff-boxes; announced persons previously to their entrance into the room in which she was; and several times mentioned the hour and the minute on a hunting watch which she held in her hand." Those who are acquainted with the waking performances of Miss Macavoy of Liverpool, will experience no difficulty in understanding the sleeping performances of Miss Pigeaire of Montpellier.

Somnam-
bulism.

Somner
||
Song.

SOMNER, WILLIAM, an eminent English antiquary, was born at Canterbury in 1606. His first treatise was the *Antiquities of Canterbury*, which he dedicated to Archbishop Laud. He then applied himself to the study of the Saxon language; and having made himself master of it, he perceived that the old glossary prefixed to Sir Roger Twisden's edition of the laws of King Henry I. printed in 1644, was faulty in many places; he therefore added to that edition notes and observations valuable for their learning, with a very useful glossary. His *Treatise of Gavelkind* was finished about 1648, though not published till 1660. Somner was zealously attached to King Charles I.; and in 1648 he published a poem on his sufferings and death. His skill in the Saxon tongue led him to inquire into most of the European languages, ancient and modern. He assisted Dugdale and Dodsworth in compiling the *Monasticon Anglicanum*. His *Saxon Dictionary* was printed at Oxford in 1659. He died in 1669.

SOMPRIE, a town of Hindustan, in the province of Cashmere, situated on the east side of the Jhyllum river. Long. 73. 25. E. Lat. 34. 17. N.

SONATA (*Ital.*), a piece of music, consisting of various movements for a single instrument, with or without accompaniment. The name has sometimes been given to certain vocal compositions, in which all the voices are equally essential. Some of the most remarkable modern sonatas are for the pianoforte, such as those of Haydn, Mozart, Beethoven, Clementi, Dussek, &c. Formerly sonatas were classed as *sonate di camera* and *sonate di chiesa*, i. e. *chamber-sonatas* and *church-sonatas*, on account of their difference of style, and the place of performance.

SONATINA (*Ital.*), a short and easy sonata.

SONDERHAUSEN, the capital of the principality of Schwartzburg-Sonderhausen, in Germany, stands on the river Wipper, at the junction of the Bebra with that stream. It is well built, and the castle on which the prince resides is situated on a hill overlooking the city; it is a venerable object, with some pleasing promenades near to it. The city contains a gymnasium, two churches, and an orphan-house, 460 dwellings, and 3600 inhabitants. Long. 10. 45. 1. E. Lat. 51. 22. 33. N.

SONDRE GRUND, or **BOTTOMLESS**, an island in the South Pacific Ocean, discovered by La Maire and Schouten in 1616. It is about twenty leagues in circumference. Long. 148. W. Lat. 15. S.

SONDRIO, a delegation of the Austrian kingdom of Lombardy, extending over 1139 square miles, is bounded on the north by Switzerland, on the east by the Tyrol, on the south by Bergamo, on the south-west by Como, and on the west by Switzerland. It comprehends an extensive valley, with lofty mountains on both sides, sometimes called the Valteline. It contains one city, six towns, and seventy-eight villages, with 91,600 inhabitants. The capital is a city of the same name, situated at the entrance of the valley, on the river Moller. It contains 3480 inhabitants.

SONEHUT, a small town and mud-fort of Hindustan, in the province of Gundwana. Long. 82. 33. E. Lat. 23. 33. N.

SONEPOUR, a town of Hindustan, in the province of Orissa, situated on the west bank of the Mahanuddy, at its confluence with the Taile river. Long. 83. 30. E. Lat. 20. 47. N.

SONG, in *Music*, in a general sense, applies to melody, whether vocal or instrumental. It is usually applied to an air adapted to the words of a short poem. Sometimes, with an adjunct, it means a particular form of melody, as *plain song* (*Fr. plain chant; Ital. canto piano, or canto fermo*). Among songs, the most characteristic and interesting are the national ones of various countries. To the influence of national song may be traced those remarkable changes and improvements in the style of melody, with regard to free-

dom and expression, that are so perceptible in the music of professed composers within the last two centuries.

SONG OF BIRDS. See **SINGING**, and *Philosophical Transactions*, vol. lxiii.

SONGHUR, a town of Hindustan, in the Gujerat peninsula, situated in a wild country, twenty-five miles north-west from Wankaner. Near it is a very ancient temple dedicated to the sun, and adorned with a variety of sculptures, in a style greatly superior to any modern works by the Hindus. In the interior of this temple is a male figure, three feet high, with uplifted hands, each holding an image of the sun; and on his two sides are two smaller idols of the same kind. There are also two other temples, one of which contains the figure of Bhavani standing on an animal resembling a tortoise, and surrounded by female attendants. There is no record concerning the time when these temples were built.

SONGI, a small river on the eastern coast of Malacca, falls into the China Sea. Lat. 2. 10. N.

SONGKIANG, a city of China, of the first rank, in the province of Kiangnan. It is situated on the great canal, very conveniently for trade, which is carried on to a considerable extent in calicoes and other cotton cloths. It has four large cities under its jurisdiction. It is 560 miles south of Pekin. Long. 120. 44. E. Lat. 31. N.

SONG-MEN-CHAN, a small island near the coast of the province Tchekiang, in China. Long. 121. 21. E. Lat. 31. N.

SONGOA, an island in the Straits of Malacca. It is about fifty miles in circumference. Long. 100. 30. E. Lat. 2. 18. N.

SOOLOO ISLES. These isles, about sixty in number, derive their name from Sooloo, the principal island in the group. They form a chain which extends in a north-east and south-west direction, from the north-eastern extremity of Borneo to the western extremity of Magindanao, and from the 4th to the 7th degrees of north latitude. The island of Sooloo is about thirty miles in length by twelve in average breadth, and contains 60,000 inhabitants. It lies midway between the islands of Borneo and Magindanao, is well cultivated, and affords a fine prospect from the sea; nor has it any certain rainy seasons, like the other Malay islands. This is owing to the moderate height of the hills not intercepting the clouds in their passage from the sea. Most rain falls, however, during the south-west monsoon, and also at the change of the monsoon, especially the autumnal. But these changes are not followed by any storms, and very seldom at any other time, so that the island enjoys almost a perpetual summer. There are several good harbours among these islands, particularly at Bewabewa, Tavitave, Tappool, Secassee, between Boobooan and Tapeantana, south of Basselan. The harbour of Bewan, the capital of Sooloo, is not good, except during the south-west monsoon. This place is situated on the sea-coast, on the north-west part of the island, and is of considerable size. The houses are built after the manner of the Malays, elevated about four feet from the ground with bamboos, of which the floors also are made. The island of Sooloo being small in proportion to its population, habits of industry prevail, and great attention is paid to agriculture. Rice is planted; but it is a precarious crop, owing to the uncertainty of the rains. Many roots are in consequence cultivated in its stead, namely, the Spanish or sweet potatoe, and yams of different species. They have abundance and variety of every species of tropical fruit. The oranges are equal in quality to those in China: they have also a fruit called jack or nanka, durians, a kind of large custard apple, called madang, mangoes, mangustines, rambustines, and a fruit they call bolona, like a large plum or mangoe, white inside. The trees in the woods are loaded with fruits, which ripen well, and are not injured by too much mois-

Songhur
||
Sooloo
Isles.

Soonda. ture. The Sooloos, from the great number of the Chinese that are among them, have learned from them the art of gardening; and they ingraft and improve their fruits.

Wild elephants are to be found in the woods; which is a remarkable circumstance, considering that the island is small and populous. Spotted deer, goats, and black cattle, are also abundant. Wild hogs abound, and do much mischief; but the natives have few sheep. They have, however, a good breed of horses, which are trained to trot, but not to gallop. After harvest the inhabitants hunt both the elephants and the wild hogs, with a view to destroy them.

The island of Sooloo was formerly the centre of an extensive trade, and was frequented by ships from Japan, which imported silver, amber, silks, chests, cabinets, and other curiosities made of fragrant woods, besides great quantities of silks and porcelain from China. It was also visited by vessels from Java, Sumatra, Ceylon, and the coast of Coromandel, with valuable cargoes. This trade has greatly declined. The intercourse with China is now confined to two junks, which arrive annually from Amoy with cargoes of brass salvers, iron, sugar-candy, raw silk, black nankeen, white linen of a strong fabric, china ware, flowered silks, besides tea, cutlery and other hard ware, brass wire, gongs, beads of all colours, little swan-shot, fire-works, &c. In return they export to China biche de mer, black and white wax, pearl-oyster shells, bird-nests, and tortoise-shell; also a sea-weed used as gum or glue, and other articles, such as Carooang oil, clove-bark, black wood, ratans, sago, various barks for dyeing, cassia, pepper, native camphire, sandal-wood, curious shells for grottoes, pearls, and spices. These islands are also occasionally visited by country ships, which import articles of European manufacture, such as brasiery, cutlery, cloth, gunpowder, fire-arms, manufactures in glass, iron, opium, piece-goods, saltpetre, shot, swords, tin ware, watches, sugar, tobacco, &c. From Borneo are imported sago, biche de mer, cowries, and tortoise-shell. Rice is imported from Magindanao, and is paid for with Chinese goods. Cotton manufactures from Celebes complete the list of imports. There is a famous pearl-fishery at Sooloo and the neighbouring islands.

These islands are governed by a hereditary prince or sultan, whose power is, however, counterbalanced by the nobles. The Sooloos seldom venture from home in their own vessels, except for the purpose of predatory excursions to make slaves among the Philippine Islands. They are warlike in their habits, though they depend less on fire-arms than on the lance, sword, and dagger, in the use of which they are very dexterous. The inhabitants have reached a higher stage of civilization than is generally attained in the Asiatic islands. The women are not strictly confined, as in many Mahomedan countries. In their houses are domesticated many Philippine and some Spanish slaves, who are purchased from the Illanos and Magindanese cruisers. Notwithstanding their boasted civilization, murder is a crime extremely common among them, and occurs on the least provocation. In 1800 they treacherously assassinated the captain of a country ship, and his boat's crew; and afterwards made an attack on the ship, but were repulsed.

Of the early history of these islanders little is known. They assert, that they once formed a part of an ancient Bornean empire, founded by the Chinese. But the Magindanese assert that they were formerly subject to them. From the period when the Spaniards obtained possession of the Philippines, they have been engaged in a constant warfare with the Sooloos, but with little advantage to themselves, being always repelled in their attempts to obtain possession of these islands.

SOONDA, a town and district of Hindustan, in the province of North Canara. The district, which is small, is situated between the 14th and 15th degrees of north latitude, above the Western Ghauts. Formerly the country

was well cultivated, and produced fine timber and pepper, betel nut, cardamoms, and plantains. Towards the eastern division of the country, the great object of agriculture is rice. Having been the seat of war between Hyder and the Mahrattas, it was greatly wasted by the former in 1763, and its rajah compelled to fly for protection to Goa; on which occasion he surrendered the whole of his territory below the Ghauts for a stipulated pension. In 1799 the Soonda district became the property of the British, with whom it remains. The capital, of the same name, was formerly an extensive and populous town, and was defended by strong fortifications, which were levelled by Hyder, who also nearly destroyed the town. Long. 74. 58. E. Lat. 14. 34. N.

SOONDIA, a town of Hindustan, in the province of Sind, situated on the Indus, on the route from Tatta to Hyderabad. Lat. 24. 58. N.

SOONEL, a town of Hindustan, in the province of Malwah, belonging to the Mahrattas, 60 miles south by east from Kotah. It is regularly built, with streets at right angles, and is of considerable extent. Long. 76. 5. E. Lat. 24. 21. N.

SOONERGONG, or **SUNERGONG**, a town of Bengal, situated on one of the branches of the Brahmapootra. It was once a large city, the provincial capital of the eastern division of Bengal, and famous for its manufactures of muslin and other fine cottons. It is now reduced to a mere village, principally inhabited by weavers, and the city of Dacca has risen on its downfall. Long. 90. 43. E. Lat. 23. 39. N.

SOONGUR, a town of Hindustan, in the province of Gujerat, 39 miles east by south from Surat. Long. 73. 38. E. Lat. 21. 8. N.

SOONPUT, a small town of Hindustan, in the province of Delhi. To the north is a handsome mausoleum of Khizer Khan, an Afghan nobleman of the family of Shere Shah. The adjacent country was greatly benefited by the canal dug by Aly Merdan Khan. Orders have been given by the British government to repair the canal, which will aid the country to recover from the desolate state in which it has been for some years past. Long. 76. 53. E. Lat. 29. N.

SOONTABURDAR, in the East Indies, an attendant, who carries a silver bludgeon in his hand, about two or three feet long, and runs before the palanquin. He is inferior to the chubdar; the propriety of an Indian newaury requiring two soontaburdars for every chubdar in the train. The chubdar proclaims the approach of visitors, &c. He generally carries a large silver staff about five feet long in his hands; and among the nabobs he proclaims their praises aloud as he runs before their palanquins.

SOOPOOR, a town of Hindustan, in the Rajpoot territories, province of Ajmeer. It is the capital of a small principality, and is 65 miles north-east from Kotah. Long. 76. 45. E. Lat. 25. 43. N.

SOOROOTOO ISLE, a small island in the Eastern Seas, situated off the western coast of Borneo, and separated from the island of Carimatia by a narrow strait, through which a ship might run if compelled by necessity. Long. 108. 40. E. Lat. 1. 45. S.

SOOROPOOR, a town of Hindustan, in the province of Bejapoor, situated on the Krishna river, nearly 130 miles south-west from Hyderabad. Long. 77. E. Lat. 16. 15. N.

SOORY, a town of Bengal, district of Birbhoom, 50 miles south-west from Moorshedabad. Long. 87. 32. E. Lat. 23. 54. N.

SOOSNEER, a considerable town of Hindustan, in the province of Malwah, 57 miles north-north-east from Oojain. Long. 76. 10. E. Lat. 23. 55. N.

SOOSOO, a small town on the west coast of Sumatra, where pepper is sometimes exchanged for gold dust. Long. 97. 10. E. Lat. 3. 45. N.

SOOSOOHOONAN, a district in the island of Java, on the south coast, formerly extending to the north coast, and

Soondia
||
Soossoo-
hoonan.

Soot
||
Sophism.

including the territories of Cheribon, and the greater part of the island. It is now much fallen from its ancient grandeur, and in the last century was divided into two parts. The prince, embarrassed by the rebellion of a powerful nobleman, made a cession of his territory to the Dutch, who in return granted him half back again, under the title of Sultan. Prior to 1740 this sovereign was proprietor of all the territory to the east of Cheribon; but he lost part of his dominions in a new contest with the Dutch. The dynasty, however, still continues; and in 1813 the capital was visited by Sir Stamford Raffles, the British governor, who was graciously received.

SOOT, a volatile matter arising from wood and other fuel along with the smoke; or rather it is the smoke itself condensed, and gathered to the sides of the chimney. Though once volatile, however, soot cannot be again resolved into vapour, but, if distilled by a strong fire, yields a volatile alkali and empyreumatic oil, a considerable quantity of fixed matter remaining at the bottom of the distilling vessel. If burnt in an open fire, it flames with a thick smoke, whence other soot is produced. It is used as a material for making sal ammoniac, and as a manure.

SOOTY, a town of Bengal, in the province of Rajshy, where an action was fought in 1763, between the British troops and those of Meer Cossim, in which the latter were defeated. Long. 88. 2. E. Lat. 24. 36. N.

SOPHI, or SOFI, a title given to the emperor of Persia, importing as much as wise, sage, or philosopher.

SOPHIS, or SOFEES, a kind of religious order among the Mahomedans in Persia, answering to what are otherwise called *dervises*, and among the Arabs and Indians *faqirs*. Some writers suppose them to be called sophis from a kind of coarse camblet which they wear, called *souf*, from the city Souf in Syria, where it is principally manufactured. The more eminent of those sophis are complimented with the title *schiek*, that is, *reverend*, much as, in Romish countries, the religious are called *reverend fathers*. Schiek Sophi, who laid the foundation of the grandeur of the royal house of Persia, was the founder, or rather the restorer, of this order. Ishmael, who conquered Persia, was himself a sophi, and greatly valued himself on that character. He chose all the guards of his person from among the religious of this order, and would have all the great lords of his court sophis. The king of Persia is still grandmaster of the order, and men of rank continue to enter into it, though it be now fallen under some contempt.

SOPHISM, in *Logic*, a specious argument, having the appearance of truth, but leading to falsehood. Sophisms are reduced by Aristotle into eight classes, an arrangement so just and comprehensive, that it is equally proper in present as in former times. 1. *Ignoratio elenchi*, in which the sophist seems to determine the question, while he does it only in appearance. Thus the question, Whether the excess of wine be hurtful? seems to be determined by proving, that wine revives the spirits and gives a man courage; but the principal point is here kept out of sight, for still it may be hurtful to health, to fortune, and reputation. 2. *Petitio principii*, a begging of the question, or taking for granted that which remains to be proved; as if any one should undertake to prove that the soul is extended through all the parts of the body, because it resides in every member. This is affirming the same thing in different words. 3. Reasoning in a circle; as when the Romanists prove the Scriptures to be the word of God by the authority of the church, and the authority of the church from the Scriptures. 4. *Non causa pro causa*, or the assigning of a false cause to any effect. Thus the supposed principle, that nature abhors a vacuum, was applied to explain the rising of water in a pump, before Galileo discovered that it was owing to the pressure of the atmosphere. In this way the vulgar ascribe accidents to divine vengeance; and the heresies and

infidelity of modern times are said to be owing to learning. 5. *Fallacia accidentis*, in which the sophist represents what is merely accidental as essential to the nature of the subject. 6. By deducing a universal assertion from what is true only in particular circumstances, and the reverse: thus, some men argue, "transcribers have committed many errors in copying the Scriptures, therefore they are not to be depended on." 7. By asserting any thing in a compound sense which is only true in a divided sense. So, when the Scriptures assure us that the worst of sinners may be saved, it does not mean that they shall be saved while they remain sinners, but that if they repent they may be saved. 8. By an abuse of the ambiguity of words. Hume reasons thus, in his Essay on Miracles: "Experience is our only guide in reasoning concerning matters of fact; now we know from experience, that the laws of nature are fixed and invariable. On the other hand, testimony is variable, and often false; therefore, since our evidence for the reality of miracles rests solely on testimony which is variable, and our evidence for the uniformity of the laws of nature is invariable, miracles are not to be believed." The sophistry of this reasoning depends on the ambiguity of the word *experience*, which in the first proposition signifies the maxims which we form from our own observation and reflection; in the second it is confounded with testimony; for it is by the testimony of others, as well as our own observation, that we learn whether the laws of nature are variable or invariable. The Essay on Miracles may be recommended to those who wish to see more examples of sophistry; as we believe most of the eight species of sophisms which we have mentioned are well illustrated by examples in that essay.

SOPHIST, an appellation assumed in the early periods of Grecian history, by those who devoted their time to the study of science. This appellation appearing too arrogant to Pythagoras, he declined it, and wished to be called a *philosopher*; declaring that, though he could not consider himself as a wise man, he was indeed a lover of wisdom. True wisdom and modesty are generally united. The example of Pythagoras was followed by every man of eminence, while the name *sophist* was retained only by those who with a pomp of words made a magnificent display of wisdom upon a very slight foundation of knowledge. Those men taught an artificial structure of language, and a false method of reasoning, by which, in argument, the worse might be made to appear the better reason. In Athens they were long held in high repute, and were supported, not only by contributions from their pupils, but by a regular salary from the state. They were among the bitterest enemies of the illustrious Socrates, because he embraced every opportunity of exposing to contempt and ridicule their vain pretensions to superior knowledge, and the pernicious influence of their doctrines upon the taste and morals of the Athenian youth.

SOPHOCLES, the famous tragic poet, was the son of Sophilus, an Athenian, and was born in the year 495 before Christ. Although the father was only a mechanic, the son enjoyed the advantage of a good education. Superior vigour and address in the exercises of the palæstra, and skill in music, were the great accomplishments of young men in the states of Greece. In these Sophocles excelled; nor was he less distinguished by the beauty of his person. He was also instructed in the noblest of all sciences, civil polity and religion: from the first of these he derived an unshaken love of his country, which he served in some embassies, and in high military command with Pericles; from the latter he was impressed with a pious reverence for the gods, manifested by the inviolable integrity of his life. But his studies were early devoted to the tragic muse; the spirit of Æschylus lent a fire to his genius, and excited that noble emulation which led him to contend with, and sometimes to bear away the prize from, his great master. He wrote forty-three

Sophist
||
Sophocles.

Soping
||
Sora.

Sorau
||
Sorites.

tragedies, of which seven only have escaped the ravages of time. Having testified his love of his country by refusing to leave it, though invited by many kings, and having enjoyed the uninterrupted esteem and affection of his fellow-citizens, which neither the gallant actions and sublime genius of Æschylus, nor the tender spirit and philosophic virtue of Euripides, could secure to them, he died in the beginning of the year 405, at the very advanced age of ninety.¹ The burial-place of his ancestors was at Decelia, which the Lacedæmonians had at that time seized and fortified: but Ly-sander, the Spartan chief, permitted the Athenians to inter their deceased poet; and they paid him all the honours due to his love of his country, integrity of life, and high poetic excellence. Æschylus had at once seized the highest post of honour in the field of poetry, the true sublime: to that eminence his claim could not be disputed. Sophocles had a noble elevation of mind, but tempered with so fine a taste, and so chastened a judgment, that he never passed the bounds of propriety. Under his conduct the tragic muse appeared with the chaste dignity of some noble matron at a religious solemnity; harmony is in her voice, and grace in all her motions. From him the theatre received some additional embellishments; but his distinguished excellence is in the judicious disposition of the fable, and so nice a connection and dependence of the parts on each other, that they all conduce to make the event not only probable, but even necessary. This is peculiarly admirable in his King Œdipus; and in this important point he is far superior to every other dramatic writer of antiquity.

The ingratitude of the children of Sophocles is well known. They wished to become immediate masters of their father's possessions, and therefore, tired of his long life, they accused him before the Areopagus of insanity. The only defence the poet made, was to read his tragedy of Œdipus at Colonus, which he had lately finished; and he then asked his judges, whether the author of such a performance could be charged with insanity. The father upon this was acquitted, and the children returned home covered with shame and confusion.

The editions of Sophocles are very numerous, and some of them very elaborate, but we can only enumerate the more conspicuous. The *editio princeps* was published by Aldus, Venet. 1502, 8vo. This was followed by an edition published by the heirs of P. Junta, Florent. 1522, 4to; and another published by B. Junta, Florent. 1547, 4to. The text of Aldus was the basis of all the editions which preceded that of Turnebus, Paris. 1553, 4to. This is among the best of the early editions. We must not omit those of H. Stephanus, Paris. 1568, 4to, and of Canter, Antwerp. 1579, 12mo. The text of Turnebus was chiefly adopted in all the succeeding editions till that of Brunck, Argent. 1786, 2 tom. 4to. This is a very elaborate as well as splendid edition, and strikingly displays the editor's acuteness and learning. The same able critic published two octavo editions, each in two volumes. We now descend to the edition of Erfurdt, Lips. 1802-11, 8 tom. 8vo. The tragedies of Sophocles have been translated into many different languages. An English version, which was favourably received, was published by Dr Francklin, Greek professor at Cambridge, Lond. 1759, 2 vols. 4to. Another was subsequently published by Mr Potter, Lond. 1788, 4to.

SOPING, a district or principality of the island of Celebes, formerly one of the most extensive in the country. In 1775 it was governed by its own king.

SOPRA, a river of Hindustan, which rises in the province of Malwah, and joins the Gilly Sinde river, after which their united streams fall into the Chumbul.

SORA, a city of Italy, in the Neapolitan province of Terra di Lavoro, the capital of a district of its own name.

It stands on the banks of the river Garigliano, is the seat of a bishop, and, besides the cathedral, has five churches, and 7950 inhabitants.

SORAU, a circle of Prussia, in the government of Frankfurt, which extends over 513 square miles, with 46,400 inhabitants. The capital is the town of the same name. It stands on a large plain, is well built, and contains 430 houses, with 4060 inhabitants, who manufacture large quantities of cotton goods.

SORBONNE, or SORBON, the house or college of the faculty of theology established in the old university of Paris. It was founded in 1252, by St Louis, or rather by Robert de Sorbon his confessor and almoner, first canon of Cambray, and afterwards of the cathedral of Paris; who gave his own name to it, which he himself took from the village of Sorbon or Serbon, near Sens, where he was born. The foundation was laid in 1250; Queen Blanche, in the absence of her husband, furnishing him with a house which had formerly been the palace of Julian the apostate. The king afterwards gave him all the houses he had in the same place, in exchange for some others. The college was magnificently rebuilt by the Cardinal de Richelieu. The institution was designed for the use of poor students in divinity.

SORBONNE was also used in general for the whole faculty of theology at Paris, as the assemblies of the whole body were held in the house of the Sorbonne, and the bachelors of the other houses of the faculty came hither to hold their *sorbonnique*, or act for being admitted doctor of divinity.

SORCERY, or MAGIC, the power which some persons were formerly supposed to possess, of commanding the devil and the infernal spirits, by skill in charms and invocations, and of soothing them by fumigations. See MAGIC and AP- PARITIONS.

SORIA, one of the four departments into which the province of Old Castille, in Spain, is divided. Its extent is 341 square leagues, and its population amounts to 257,537 souls. It is in general a hilly district, and in some parts very mountainous. The plains are fertile, especially that of Rioja, and yield abundance of wheat and barley, and in some years it has a surplus of both these productions. Its wine is good, but not abundant; and it is deficient in a supply of oil, which is procured from the more southern provinces. This province furnishes to commerce a great proportion of the fine wool of the merinos. That of Soria is not equal in fineness to what is produced in Segovia, but is however of a good quality; and the quantity annually sent away amounts to about 2,250,000 pounds.

SORIA, a city of Spain, in New Castille, the capital of the department of that name. It is situated on the north bank of the river Duero, but too near its source to derive any benefit as to navigation. In the vicinity there are excellent pastures for sheep, with houses of various kinds to shelter them when the weather is more than usually inclement, or when they are shorn. It is not a large city, nor are the public buildings of a nature to merit a detailed description; but the extensive ruins of the ancient Numantia invite the notice of every lover of Roman antiquities. Soria contains thirteen churches, eleven monasteries, four hospitals, and 6000 inhabitants. The manufacture of silk stockings employs eighty-two looms. Some of the inhabitants are employed in soap-boiling, tanning, and in the manufacture of cloth. Lat. 41. 48. N.

SORIAN, a river of Celebes, on the west coast, which falls into the sea.

SORITES, in *Logic*, a species of reasoning, in which a great number of propositions are so linked together, that the predicate of the one becomes continually the subject of the next following, till at last a conclusion is formed by bringing together the subject of the first proposition and

¹ Clinton's Fasti Hellenici, vol. ii. p. 23, 57, 83.

Sorrento
||
Sortino.

the predicate of the last. Such was that merry argument of Themistocles, to prove that his little son under ten years old governed the whole world: "My son governs his mother; his mother me; I the Athenians; the Athenians the Greeks; Greece commands Europe; Europe the whole world: therefore my son commands the whole world."

SORRENTO, a city of Italy, in the province of Naples. It is finely situated among olive, citron, and pomegranate trees, and is the seat of an archbishop. It is on the sea-coast, and has some foreign trade. The chief occupation is collecting and spinning silk. It was the birth-place of the poet Tasso. The surrounding hills are chiefly composed of tufa, which was originally lava; and the doors and window-seats are generally formed of that substance. It contains 4240 inhabitants.

SORTILEGE (*Sortilegium*), a species of divination performed by means of *sortes* or lots. The *sortes Prænestinæ*, famous in antiquity, consisted in putting a number of letters, or even whole words, into an urn; and then, after shaking them together, they were thrown on the ground; and whatever sentences could be made out of them constituted the answer of the oracle. To this method of divination succeeded that which has been called the *sortes Homericae* and *sortes Virgilianæ*; a mode of inquiring into futurity which undoubtedly took its rise from a general custom of the oracular priests of delivering their answers in verse. It subsisted a long time among the Greeks and Romans, and being from them adopted by the Christians, it was not till after a long succession of centuries that it became exploded. Among the Romans it consisted in opening some celebrated poet at random, and among the Christians the Scriptures, and drawing, from the first passage which presented itself to the eye, a prognostic of what would befall one's self or others, or direction for conduct when under any exigency. There is good evidence that this was none of the vulgar errors; the greatest persons, philosophers of the best repute, admitted this superstition. Socrates, when in prison, hearing this line of Homer,

Within three days I Phthia's shore shall see,

immediately said, within three days I shall be out of the world; gathering it from the double meaning of the word *Phthia*, which in Greek is both the name of a country and signifies corruption or death.

SORTINO, a city of the island of Sicily, in the province of Noto. It stands on a healthy spot on a gentle elevation, the ancient Xuthinum, 130 miles from Palermo, and is watered by a small stream. It contains 7300 inhabitants.

SORTINSKOI, a village of Tobolsk, in Asiatic Russia, seventy-two miles south-south-west of Beresof. Sortinskoi

||
Sound.

SOSVA, the name of two considerable rivers in Asiatic Russia, in the government of Tobolsk. The first has a course of 160 miles. It rises in the Oural Mountains, about the sixty-fifth degree of north latitude, and running almost due east, falls into the Obi near Beresof, after receiving a smaller river of the same name, called the Little Sosva. The other river rises somewhat farther to the north, in the same chain of hills, and running southwards about 200 miles, joins the Sosva, where their united streams take the name of Tauda.

SOTERIA, in *Antiquity*, sacrifices offered to the gods for delivering a person from danger; as also poetical pieces composed for the same purpose.

SOUDAN, a kingdom of Africa, situated between 11° and 16° north latitude, and 26° and 30° east longitude. See AFRICA.

SOUERICK, a town of Armenia, in the pachalic of Ourfa, and on the road from Ourfa to Diarbekir. It contains about 500 inhabitants, with three mosques and a strong castle. It is sixty miles north-east of Ourfa.

SOUGH, among miners, denotes a passage dug under ground to convey off waters from mines.

SOUI-TCHEOU, a city of China, of the first rank, situated at the confluence of the rivers Yan and Kincha, in a fertile though mountainous country. Long. 104. 23. E. Lat. 28. 40. N.

SOUL, the principle of perception, memory, intelligence, and volition, in man; which, since the earliest era of philosophy, has furnished questions of difficult investigation, and materials of keen and important controversy.

SOUND. So many things relating to this subject have been already treated at considerable length under the article ACOUSTICS, that what we now propose shall be chiefly confined to the propagation of sound in the atmosphere, which, as Laplace observes, affords the most important application which has yet been made of the theory of elastic fluids. In this we shall first give the results of the principal attempts which have been made with the view of determining the velocity of sound experimentally; and shall notice more particularly some of them which are of a later date, and were made with far greater precautions than any of those mentioned under the article just cited. We shall then advert to various important oversights and imperfections which still attach to this department of science, and to certain improvements of which it seems to be susceptible.

Results of Various Experiments on the Velocity of Sound.

Observers.	Date.	Country.	Distance in Feet.	Velocity.	Temperature.	
Florentine Academicians...	1660	Italy.....	5,906	1148	...	Tentamina Acad. del Cimento.
Cassini, Huygens, &c.....	...	France.....	9,239	1151	...	Hist. Acad. Royale, lib. ii.
Flamsteed and Halley.....	...	England.....	15,840	1142	...	Phil. Trans. 1708, 1709.
Derham.....	1704	England.....	5,280 to 63,360	1142	...	Ibid.
French Academicians.....	1738	France.....	18,744 to 102,824	1106	43° F.	Mém. de l'Acad. 1738, 1739.
Cassini and Lacaille.....	1739	France.....	144,124	1110	...	Ibid.
Bianconi.....	1740	Italy.....	78,740	1043	...	Comment. Bononiensis, vol. ii.
La Condamine.....	1740	Quito.....	67,400	1112	...	La Condamine, Introd. Hist. 1751.
La Condamine.....	1744	Cayenne.....	129,360	1175	...	Mém. de l'Acad. 1745.
T. F. Mayer.....	1778	Germany.....	3,412	1105	...	Mayer, Prakt. Geometrie, 1792.
G. E. Müller.....	1791	Germany.....	8,530	1109	...	Müller, Gelehrt Anzeige, 1791.
Espinoza and Bauza.....	1794	Chili.....	53,626 to 14,071	1222.3	74° 7	Ann. de Chimie, vii. 93.
Benzenberg.....	1809	Germany.....	29,764	1093	32	Gilbert's Annalen, N. Folge, b. v.
Goldingham.....	1821	India.....	13,932 to 29,547	1086.7	32	Phil. Trans. 1823, p. 96.
Myrbach.....	1822	Germany.....	32,615	1092.1	32	Mean of eighty-eight experiments.
Arago, Matthieu, &c.....	1822	France.....	61,064	1086.1	32	Conn. des Tems, 1825.
Moll, Van Beek, &c.....	1823	Holland.....	57,971.2	1089.5	32	Phil. Trans. 1824, p. 424.
Gregory.....	1823	England.....	2,700 to 13,460	1088.1	32	Phil. Magazine, June 1824.
Parry and Foster.....	1825	Polar Regions..	12,892.9	1035.2	— 17.7	Phil. Trans. 1828, p. 97

The reduction of such results to 32° Fahrenheit is usually made conformably to the expansion of air given by Dalton, Gay Lussac, &c., which is nearly at the rate of 1.14 foot for each degree. The expansion of Rudberg, about to be noticed, being rather smaller, would slightly lessen the reduction.

Sound.

From a close examination of the twenty-eight principal experiments made in Holland in 1823, Professor Miller has, in the *Philosophical Magazine* for July 1839, deduced the following as the correct means of the results. The mean interval of the time in which sound travelled 17,669·28 metres is 51·9873 seconds. The mean temperature during these experiments was 11°·01 cent. The mean pressures of the atmosphere, and of the vapour in it, were ·74618 and ·00889 metres at 0° cent. respectively. Now, from Rudberg's experiments (Poggendorff's *Annalen*, xli. 558 and xlv. 119), which perhaps require to be repeated by others, it appears that on heating dry air from 0° cent. to 100°, under a constant pressure, its volume was increased from 1 to 1·365; hence, at the temperature θ cent., the pressure of the atmosphere and of the vapour in it being p and f respectively, the velocity of sound in English feet per second will be

$$1090\cdot77 \sqrt{\left(\frac{1 + \cdot00365\theta}{1 - \cdot375 \frac{f}{p}} \right)}.$$

This, owing to its depending on a smaller rate of expansion, exceeds 1089·5, the number in the table; but it is chiefly to be regarded as a general expression for the experimental results. The theoretical formula will be found farther on.

Chronometers employed.

With the exception of Benzenberg, who had long ago used the species of clock described below with a conical pendulum, the most of the experimenters were formerly very ill provided with any adequate means of accurately measuring the intervals of time which elapse between the flash and report of the guns, as observed at the opposite station. In 1822, the French academicians employed the stop-watch of Breguet and the chronograph of Rieussec, a species of watch, one of whose hands revolves in one second, and can, without needing to stop, be made to touch with its extremity the dial-plate at any instant, so as to leave there a dot of ink, merely by suddenly pressing a small lever. In the experiments made in Holland in 1823, a clock was used with a conical pendulum which revolved 69·433 times in a minute, and was supposed capable of determining intervals to the 100th of a second, by suddenly arresting the index without stopping the clock. By means of these machines it was supposed quite practicable to determine the interval between the sight of the flash and the arrival of the report of a gun, with such precision as to obviate all material error which might arise from this cause. The importance of this, if realized, is evident from the circumstance that each tenth of a second corresponds to 110 feet of distance.

Their results illusory.

But there is too good reason to suspect that all such ideas of attaining great accuracy in any direct measurements of the intervals of time are perfectly illusory; and that observations made with these machines can scarcely be depended on within a tenth of a second. The machines themselves may be possessed of all the perfection ascribed to them; but it would seem that the man has yet to be made who would be competent to use them. In Holland, only one centrifugal clock being employed at each station, we have no means of judging of the correctness of the observations made with it. But whoever examines the tables of results given in the *Connaissance des Temps* for 1825 (pages 364–367) will find that three and as often four machines, with as many first-rate observers, were generally employed simultaneously in determining the interval for each shot; and that instead of their results agreeing within an inconsiderable fraction, as the above ideas of great correctness would imply, they often differ by three, sometimes by four, and in one case by five tenths of a second. Something farther illustrative of this will be found under the article CLOCK AND WATCH WORK (vol. vi. p. 783), where a ma-

chine has been described for determining, by indirect means, but to almost any degree of exactness, the interval in which sound passes over a small distance. The principal part is a strong clock, without compensation or other refinement, and requiring no extraordinary sort of being to observe with it.

Sound.

Although many eminent philosophers have laboured much to improve and perfect the various reductions which it is considered necessary to make on the experimental results, there is still a mistake regarding the exact influence of the wind. It seems always to be supposed that the effects of a steady wind are entirely obviated or compensated by taking the mean of the velocities of such sounds as are simultaneously produced at the two opposite stations, and also reciprocally observed at these respectively. This is in effect the view of the matter taken by Professor Moll. (*Philosophical Transactions* for 1824, p. 426.) Many other philosophers express the same opinion, and in particular Sir John Herschel, who recommends that all experiments on the velocity of sound be made, if possible, either in calm weather or in a direction at right angles to that of the wind. But so far is the result under this last arrangement from being entirely unaffected by the wind, that the error to which we now allude is then a maximum; and indeed in every case in which the direction of the wind is inclined to the base line, there is still a small error, which cannot be obviated by the reciprocal method.

The earlier experimenters gave themselves no concern about the influence of the wind; but its effect was in some degree eliminated by the arrangements adopted by the French academicians in 1738, though in so imperfect a manner as to leave considerable doubt regarding the accuracy of their result. In order to clear up this point, the Marquis Laplace requested the board of longitude to repeat the experiments, with the precaution of exciting sounds more nearly at the same instant from both ends of the base, in the expectation that the effects of the wind would be thereby completely obviated. The experiments were accordingly repeated in June 1822, though with no greater precision in this respect than that the times of firing the opposite shots still differed about five minutes from being simultaneous. In the experiments made in Holland in 1823, matters were so much better arranged, that the difference in the times scarcely ever amounted to a second. However, M. Arago has remarked, that when the wind is very unsteady, or comes in sudden gusts, it may still affect the mean result, especially since a sudden gust may interfere with the one sound, and yet miss the other altogether. But even when the wind is perfectly steady, the reciprocal method cannot be quite correct, unless the wind also blows directly from the one station to the other. In every other case it is more or less inaccurate, owing to the circumstance that sound is not propagated in parallel lines, but issues from its source in lines which radiate or diverge to every side; so that the same sonorous ray which, during a calm, would pass directly from the one station to the other, will not reach the latter at all when deflected by the wind into a different direction. Had our limits permitted, we should have endeavoured to show that, by applying to this the well-known principles of the composition of forces, the mean of the velocities of the reciprocal sounds will, owing to the action of the wind, come short of the true velocity, by a quantity which will in all cases be nearly expressed by $\frac{W^2}{2S} \sin^2 A$; where W is the velocity of the wind, S that of sound in still air, and A the angle which the direction of the wind makes with the base line. This correction, though generally very small, may often be several times greater than some which are usually taken into account, especially that arising from the effect of the difference of latitude and of the height of the place above the sea, on the force of gravity. For such we beg to refer to the *Philosophical Trans-*

Sound. actions for 1824, 1828, and 1830. The pendulum, however, seems a more certain means of determining the differences in the force of gravity, than any merely theoretical formula, which cannot be expected to provide for particular local attractions. Besides, we suspect that during experiments on the velocity of sound, attention has not always been paid to the velocity and direction of the wind; and still more rarely have these been registered and published, so as to afford data for applying the requisite correction.

In the Reports of the British Association for 1833 and 1836, we find two able and interesting articles by Professor Challis, on the mathematical theory of fluids. Among other things, he treats at considerable length on the theory of sound, giving an analysis and notices of various essays on that subject. But these the learned professor seems, after all, never to have thoroughly examined, otherwise he could not have failed to discover that, in the mathematical investigations employed in several of the papers on which he has bestowed the largest share of commendation, there are various fundamental errors and inconsistencies, which naturally enough have led their authors into results which, independently of every other consideration, are more or less erroneous, because palpably incompatible with each other and with the premises from which they are professedly deduced. Fallacies of the sort in question have been pointed out in the Edin. Phil. Journ. (for Oct. 1826, p. 335, and July 1827, p. 153), as also in various numbers of the Quarterly Journal of Science for 1829. Some of the same errors have been likewise noticed, though not so early as in the first-mentioned journal, by an eminent Italian philosopher, Mr Avogadro, in the *Memorie dell' Accademia reale della Scienze di Torino* (vol. xxxiii. p. 237), and also in a separate tract of his. Several notable instances of the like sort have been discussed and exposed in the article HYGROMETRY; but it is only one or two examples which we can notice here.

Researches
of Laplace
and Poisson.

With the view of accounting for the excess of the actual velocity of sound over that given by Newton's formula, it was very ingeniously suggested, in a general way, by the Marquis Laplace, about the beginning of the present century, that, in the propagation of sound, the minute rises and falls of temperature occasioned by the alternate condensations and dilatations of the air, should tend to augment the disturbance in the equilibrium of the pressure, and consequently to accelerate the transmission of sound. He did not, however, till long after, assign the form or amount of the correction for such acceleration. The first attempt toward this seems to be that of Biot in 1802 (*Journal de Physique*, tome lv. p. 173). But M. Poisson both claims and gets the no small credit of having very considerably anticipated Laplace in giving the precise form of the correction. This he is alleged to have done in a formula for the velocity of sound, communicated to the Institute as early as the year 1807, and shortly after published in the *Journal de l'Ecole Polytechnique* (cahier xiv.), and which is meant to consist of Newton's formula multiplied by a constant factor $\sqrt{1+k}$. But whilst it must be admitted that no one has written to better purpose on the theory of sound than M. Poisson has done, there seems to be a very general mistake regarding that factor. The formula is

$$\sqrt{\frac{gh}{D} \left(1 + \frac{aw}{(1+a\theta)\gamma} \right)} = \sqrt{\frac{gh}{D} (1+k)}.$$

In this he defines g to represent the force of gravity; h the height of the barometer; D the ratio of the density of the air to that of mercury; θ the temperature of the air; w the augmentation of that temperature occasioned by a condensation γ , and so small as to be considered proportional to γ ; also $a = .00375$ for the co-efficient of the dilatation of the gases. But these evidently cannot make k constant, as the sequel requires it to be. After introducing the same for-

mula and explanation of symbols in another memoir inserted in *Annales de Chimie* for May 1823, he proceeds to

Sound.

show that the factor $1 + \frac{aw}{(1+a\theta)\gamma}$, which for greater brevity he there calls simply k , is equal to the ratio of the specific heat of air under a constant pressure to its specific heat under a constant volume; which would identify $\sqrt{k}$ with the above-mentioned correction given by Laplace himself, for the first time only, in the same *Annales* for November 1816, and even then without demonstration. But it is worthy of particular notice, that the reason why the factor k in this case comes to be a correct expression for the ratio of the specific heats, is entirely owing to M. Poisson's there using

γ as proportional, not to w , as above defined, but to $\frac{aw}{1+a\theta}$.

This will be readily seen on-examining the *Annales* for May 1823 (p. 8 and 14), where, having put $\gamma = \frac{d\varrho}{\varrho}$, and $w = d\theta$, he

deduces $\frac{ad\theta}{1+a\theta} = (k-1)\frac{d\varrho}{\varrho}$; and hence $k = 1 + \frac{a\varrho d\theta}{(1+a\theta)d\varrho} = 1 + \frac{aw}{(1+a\theta)\gamma}$. Indeed, otherwise, $\sqrt{k}$ could neither have

been constant, nor coincided with the correction of Laplace.

The leading principle in these formulæ therefore is, that as long as the total heat in the air undergoes no change (which may safely be supposed to be the fact, during a much longer interval than the theory of sound requires), it is not γ and w , but the differentials of $\log. (1+a\theta)$ and of $\log. \varrho$ which are always held to be proportional; and, consequently, any changes, whether great or small, in these two logarithms themselves, must also be proportional; so that the general expression for the ratio of the specific heats, whether the simultaneous changes of ϱ to ϱ' , and of θ to θ' , be great or small, will be

$$1 + \frac{\log. (1+a\theta') - \log. (1+a\theta)}{\log. \varrho' - \log. \varrho} = k.$$

The above inconsistency seems to have sadly misled M. Poisson's readers, particularly Professor Challis, as already cited; but it is virtually included in a more serious oversight, about to be noticed, which originated in the *Mécanique Céleste*, and has been generally more or less adopted, with implicit confidence, into almost every subsequent essay on the theories of heat and sound. In particular, it forms a leading feature in the works of Poisson, in Professor Kelland's Theory of Heat, and in Mr Lubbock's recent essay On the Heat of Vapours, which seems to have been hastily compiled, or, at any rate, from very incongruous materials.

When reviewing the first four volumes of the *Mécanique Céleste*, Professor Playfair expressed great doubts if there were then a dozen of persons in Britain qualified to peruse them. But whatever may now be the number of those who are content with merely reading the ordinary letter-press of that celebrated work, it is certain that almost none give themselves the trouble of thoroughly sifting the mathematical investigations, otherwise the serious oversights and inconsistencies which occur in some of them would be better known and appreciated, particularly the inaccuracies which pervade the greater part of the long chapter devoted to the velocity of sound. Of these, however, we shall here, for brevity's sake, take only one instance, which is selected, not so much on its own account, but because it unfortunately lies at the foundation of many of the formulæ and results with which the seventeen quarto pages following it are chiefly occupied. In the passage referred to (tome v. p. 127), there occurs an equation of the form

$$\varrho \frac{dq}{d\varrho} + kp \frac{dq}{dp} = 0,$$

Sound. where p is the pressure, ρ the density, and q the difference between the total quantity of heat which a given mass of air may then contain, and that which it contains at a temperature and pressure chosen arbitrarily. Also k is still a constant, expressing the ratio of the specific heats. We here state the matter in something like the more simple language and notation of M. Poisson, who, in the *Annales de Chimie* for August 1823, has readily deduced that equation from the two leading principles employed for it by Laplace, and which alone are essential to it, viz. the law of Mariotte, and the constancy in the ratio of the specific heats.¹

From integrating the preceding equation on general principles only, and without having regard to the subject in hand, it could only be inferred that q is some indetermi-

nate or arbitrary function of $\frac{p^{\frac{1}{k}}}{\rho}$. But such eminent mathematicians as Laplace and Poisson, instead of being content with this general view of the matter, ought to have perceived that the conditions of the question, particularly the two principles just specified, and with which they had set out for the purpose of finding q in terms of p and ρ , necessarily required q to be of the form $A + B \left(\frac{1}{k} \log p - \log \rho \right)$,

where A and B are constants; because this expression, independently of its being the first to present itself in the integration, is the only form or function of the above general integral which would be free from inconsistency or compatible with those two leading principles. So far, however, were they from attending to or being aware of this circumstance, that supposing themselves perfectly at liberty

to adopt any particular function of $\frac{p^{\frac{1}{k}}}{\rho}$, they made choice

of $q = A + B (266.67 + \theta) p^{\frac{1}{k}-1}$; where A and B are arbitrary constants, and θ is the temperature, because ρ has been eliminated by the law of Mariotte. This form was adopted by these philosophers, that it might agree, as they supposed, with the hypothesis that the expansions of air under a constant pressure are proportional to the corresponding increments of absolute heat. But it is easily shown that such a hypothesis is quite incompatible, not only with the two leading principles, but with that very form which was on its account purposely given to q , as was first pointed out in the *Edinburgh Philosophical Journal* (for October 1826, p. 335), and afterwards more explicitly in article *HYGROMETRY* (vol. xii. p. 113), where a similar question has been consistently solved by a far more simple process of reasoning.

Ratio of the specific heats. The precise value of the above-mentioned ratio of the specific heats is considered an important element in the theory of sound. The experiments of Desormes and Clement give 1.354; those of Gay Lussac and Welter, 1.3748; and those described under the article *HYGROMETRY*, 1.3333; all of which seem to be smaller than what would reconcile the theory with the actual velocity of sound. But we shall afterwards see reason for supposing that there is still another source of acceleration, which has hitherto been over-

looked. In the *Annales de Chimie* for June 1829, and *Mémoires de l'Académie* (tome x. p. 147), M. Dulong treats at considerable length on the specific heat of elastic fluids; and with the view of obtaining the ratio in question for each of them, he assumes as demonstrated, that the actual velocity of sound, in any elastic fluid whatever, has to the velocity computed by Newton's formula the subduplicate ratio of the specific heat of that fluid under a constant pressure to its specific heat under a constant volume. But since it is only in air that the velocity of sound can be obtained by direct means, Dulong availed himself of a method previously employed by others, though by no means with complete success, as is evident from the discordance of their results. It consists in determining the velocity of propagation from the musical note rendered by a given cylindrical tube, and from the measured distance between two consecutive nodal sections or positions of minimum vibration. The pitch of the note gives the number of vibrations in a given time, and consequently the time of propagation over the measured interval, and therefore the velocity of the sound. By following a particular process, Dulong was enabled to give great precision to this method, which he practised first on atmospheric air, with the view of testing the soundness of the scheme; and by many successive trials he obtained a series of results, each of which, instead of exceeding, fell short of the velocity determined by direct observation. On finding therefore that this method failed in affording quite so great a ratio as he had expected or wished, Dulong abandoned it altogether, and finally adopted 1.421 as the ratio for air. This he obtained merely from taking the mean of a great number of the direct experiments which have been made on the velocity of sound in the open atmosphere, though it is usually quoted by others as the result of Dulong's own experiments with the musical notes from tubes. The same empirical mode of determining the ratio, which, however, does nothing for clearing up the theory, has been prosecuted still more closely by Dr Simons, in the *Philosophical Transactions* for 1830. When the number thus obtained is substituted in the formula, it certainly answers admirably; and no wonder, for it is just obtained by reasoning in a circle, which is fit to reconcile every sort of discordance.

There can be no question that great ingenuity and superior analytical skill have frequently been displayed in theoretically investigating the velocity of sound; but an important oversight, and which probably is the principal source of the remaining discrepancy between the observed and the theoretical velocities, seems to attach to all the researches of this kind with which we are acquainted, in that they are conducted upon two assumptions which are so very incompatible with each other that both cannot be true, if indeed any of them is strictly so. In the first place, it is assumed that the particles of the air, at least during a calm, vibrate accurately in the direction in which the sound is propagated. Secondly, that the air, during these vibrations, preserves or acts strictly in its fluid character. That the investigations involve the first of these assumptions, is what no one will for a moment dispute; and that they also proceed upon the second, is evident from the circumstance that the pressure of the air in such researches is always taken as

Sound.

Probable source of discordance between theory and observation.

¹ In the *Philosophical Magazine* for April 1827, it has been attempted to deduce the same equation from these two principles, incongruously coupled with a third, but with which they are utterly incompatible; and that is the needless assumption, that, under a constant pressure, the variations of absolute heat in air are proportional to those of its temperature by the common scale. But so much does the resulting equation savour of the incongruity of the data, that it has been accompanied with an admission of its being only true in one particular state of the variables, and therefore totally unfit for integration. All this might have been allowed to pass, had it not been done with the view of palming the same fatal defect upon the production of Laplace and Poisson, which however is of an essentially different character. For the equation which has been deduced from the two leading principles alone, by the accurate and consistent method of Poisson, as above cited, and also given in the *Philosophical Magazine* for November 1823, neither involves the needless assumption, nor has any dependence on a particular state of the variables, and so is equally true in every case. Nor was it till after having legitimately obtained that equation, that Poisson adopted any such assumption at all on this occasion, though, as we shall presently see, he unfortunately has done so in the sequel of his memoir, and thereby introduced all manner of inconsistencies.

Sound. strictly proportional to some particular power of the density, viz. either to the simple density, as was done by Newton, or to some higher power of it, as was in effect done by Laplace and his followers. Now, such proportionality of the fluid pressure to any uniform power of the density, would obviously require the particles constantly to observe the same uniform arrangement during their vibrations, so as to have the like distances between the adjacent particles of any small portion of the air everywhere to vary inversely as the cube root of the density, with, perhaps, the mere exception of as much difference of arrangement as is unavoidably due to the density being different in different parts of a wave of air. But it is easy to see that the two assumptions are so inconsistent that only the one of them could be strictly true; because vibrations performed accurately in the direction of the sound necessarily imply that (abstracting from the very insignificant change of distance due to the sound's being propagated in lines which are slightly diverging, because radiating from the source of sound) the distances of the particles of the air, estimated perpendicularly to the direction of the sound, would not be altered by or during these vibrations; and consequently that the density of any minute volume of the air, instead of varying alike in all its three dimensions, would vary in only one of them, namely, in the direction alone in which the sound is propagated through it.

But, independently of the incompatibility of the two assumptions, the extreme rapidity or short duration of the vibrations, whilst it gives some probability to the first, throws as much doubt on the second. Nay, any thing like a strict fulfilment of the second assumption seems, on this and various other accounts, to be extremely improbable, particularly because, in order to preserve a uniform arrangement, it would require the most of the particles, notwithstanding the rapidity of their vibrations, to describe lines deviating so much and in all manner of ways from the direction in which a clear sound is understood to be propagated, that, granting such interwoven vibrations to be possible, they could be expected to produce nothing but a very confused noise. Nor is it easy to conceive how, on that supposition, two different sounds could ever cross each other's paths without seriously interfering, which does not appear to be the fact. On the other hand, if we may not strictly adhere to the first assumption, yet, by taking a mean between the two, it would follow that the increase of the repulsion due to condensation, and the diminution of it due to dilatation, being both of them principally if not entirely confined to the direction of the sound, they would both be so much the greater in that direction; and by thus constituting an increased disturbance in the equilibrium of the repulsion reckoned in that same direction, they would have a precisely similar effect on the result, as if the pressure of the air in its otherwise supposed strictly fluid character had followed the ratio of a higher power of the density than it really does. Now, such an effect would obviously tend to shorten the duration of the vibrations, or to increase the theoretical velocity of sound, which is just the thing required in order to make it agree with observation.

The preceding remarks become far more striking with respect to the attempt which Poisson has always been considered to have made successfully (*Journal Polytechnique*, tome vii. p. 364), to show that the velocity of sound would still be the same, although the vibrations were considerable, and confined to a single straight line.

Doubts have been started if the air really consists of particles, and whether it may not rather have some undefinable constitution; but such vague considerations cannot materially alter the case, whilst there can be no question that the air, like all other matter, has inertia when at rest, and momentum when in motion; and also that as long as it is considered to preserve or act strictly in its fluid character,

the matter of which any minute volume of it consists must be uniformly distributed. For it is upon properties essentially the same with these that the above remarks are founded.

(E. E. E.)

SOUND, in *Geography*, denotes in general any strait or inlet of the sea between two headlands. The name is given by way of eminence to the strait between Sweden and Denmark, joining the German Ocean to the Baltic, being about three miles over.

SOUND-Board, the principal part of an organ, and that which makes the whole machine play. It is a reservoir, into which the wind, drawn in by the bellows, is conducted by a port-vent, and thence distributed into the pipes placed over the holes of its upper part. The wind enters them by valves, which open by pressing on the keys, after the registers are drawn, by which the air is prevented from passing into any of the other pipes besides those in which it is required.

SOUND-Board also denotes a thin broad board placed over the head of a public speaker, to enlarge or extend and strengthen his voice. Sound-boards are found by experience to be of no use in theatres, as their distance from the speaker is too great to be impressed with sufficient force. But sound-boards over a pulpit have frequently a good effect, when the case is constructed of a proper thickness, and according to particular principles.

SOUNDS, MUSICAL. See **MUSIC**.

SOUNDING, the operation of trying the depth of the sea and the nature of the bottom, by means of a plummet sunk from a ship to the bottom. There are two plummets used for this purpose; one of which is called the *hand-lead*, weighing about eight or nine pounds; and the other the *deep-sea lead*, which weighs from twenty-five to thirty pounds; and both are shaped like the frustum of a cone or pyramid. The former is used in shallow waters, and the latter at a great distance from the shore, particularly on approaching the land after a sea-voyage. Accordingly the lines employed for this purpose are called the *deep-sea lead line*, and the *hand-lead line*. The hand-lead line, which is usually twenty fathoms in length, is marked at every two or three fathoms; so that the depth of the water may be ascertained either in the day or night. At the depth of two or three fathoms there are marks of black leather; at five fathoms, there is a white rag; at seven, a red rag; at ten, black leather; at thirteen, black leather; at fifteen, a white rag; and at seventeen, a red rag.

Sounding with the hand-lead, which by seamen is called *heaving the lead*, is generally performed by a man who stands in the main chains to windward. Having the line quite ready to run out without interruption, he holds it nearly at the distance of a fathom from the plummet; and having swung the latter backwards and forwards three or four times, in order to acquire the greater velocity, he swings it round his head, and thence as far forward as is necessary; so that by the lead's sinking while the ship advances, the line may be almost perpendicular when it reaches the bottom. The person sounding then proclaims the depth of the water, in a kind of song resembling the cries of hawkers in a city. Thus, if the mark of five fathoms is close to the surface of the water, he calls, "By the mark five;" and as there is no mark at four, six, eight, &c. he estimates those numbers, and calls, "By the dip four," &c. If he judges it to be a quarter or an half more than any particular number, he calls, "And a quarter five, and a half four," &c. If he conceives the depth to be three more than a particular number, he calls it a quarter less than the next: thus, at four fathoms and three fourths he calls, "A quarter less five."

The deep-sea lead is marked with two knots at twenty fathoms, three at thirty, and four at forty, and so on to the end. It is also marked with a single knot in the mid-

Sound
||
Sounding.

Sourabaya. dle of each interval, as at twenty-five, thirty-five, forty-five fathoms, &c. To use this lead more effectually at sea, or in deep water on the sea-coast, it is usual previously to bring to the ship, in order to retard her course: the lead is then thrown as far as possible from the ship on the line of her drift, so that, as it sinks, the ship drives more perpendicularly over it. The pilot, feeling the lead strike the bottom, readily discovers the depth of the water by the mark on the line nearest its surface. The bottom of the lead being also well rubbed over with tallow, retains the distinguishing marks of the bottom, as shells, ooze, gravel, &c. which naturally adhere to it. The depth of the water, and the nature of the ground, which is called the *soundings*, are carefully marked in the log-book, as well to determine the distance of the place from the shore, as to correct the observations of former pilots.

SOURABAYA, a large and flourishing town of Java, on the north-eastern coast, and capital of a government of the same name, subordinate to that of Java. It is situated at the mouth of a river, navigable for vessels of 100 tons one mile and a half from the sea-shore. The harbour is one of the most convenient in the island; it is broad and spacious, secure against the violence of the sea and wind; and it is mentioned by Sir Stamford Raffles, that it may be rendered impregnable to any hostile attack.¹ It is formed by the approaching extremities of the islands of Java and Madura, which in some places are not above eighty-three fathoms distance for about ten or fifteen miles. This strait is not of easy navigation, but it is marked all along by buoys; and is, besides, defended by strong batteries. One of these, a circular battery, has a commanding sweep across the Strait of Madura, which is narrowest there, being opposite to the south-west end of the island of that name. The eastern entrance being impassable for large ships, the batteries are still incomplete on that side; but the north-western entrance is defended by Fort Ludowyk, distant from Gressie about six, and from Point Panka about five miles. It presents, low on the water, a hundred pieces of the finest ordnance, mounted on traversing carriages, besides some heavy mortars. The European part of the town is separated from the Chinese part, and from the native quarter, by the river; but is connected with it by a fine drawbridge. The houses are very good, some of them elegant, particularly the newly erected country-seats of private individuals. The house of the British resident at Sim-pang is a fine large building, close to the river; and near it the general hospital is unequalled in elegance and commodiousness. Sourabaya has been greatly improved within these few years, in proportion as the neighbouring town of Gressie has fallen into decay. A fine arsenal, and other extensive works, calculated for equipments on a very large scale, were formed by General Daendels at this place. Vessels are built and equipped at Sourabaya. Abundance of timber is procured from the adjoining forests, which is floated down the river that takes its rise from a large inland lake encircled with high mountains. Here is also a mint, from which silver and copper coins are issued. A new government-house was begun at Sourabaya, and was designed to be a splendid edifice; but the foundation of the front range having sunk, and endangered the building, the plan was abandoned, and that part which continued firm was converted into store-rooms. Ships from Batavia bound to China or the Philippines generally touch for refreshments at this place, especially during the north-west monsoon. The surrounding country is fertile, and shaded by thickets of bamboos, bananas, and other shrubs. The adjacent country is remarkably populous; and the villages of the Javanese, Malays, and Chinese are so

populous that they appear to be a continuation of the town. Long. 112. 55. E. Lat. 7. 14½. S.

SOURERA, a town of Hindustan, province of the Circars, and district of Ganjam. Long. 84. 37. E. Lat. 19. 53. N.

SOURGOUTE, a small town of Asiatic Russia, situated on the Obi, in a climate so severe that no grain can be raised in the neighbourhood. The town consists of 168 houses, and contains two churches. It is the residence of a commissary, who collects an annual tribute of furs from the Ostiaks, the inhabitants of the country.

SOURGOUTE, a river of Tobolsk, in Asiatic Russia, which falls into the Obi near the town of the same name, after a course of 100 miles.

SOUTCHEOUFOU, a large city of China, and capital of the province of Kiangnan, situated on the great canal, not far from its southern termination at Hangtcheoufou. It is one of the finest cities in China, noted for the beauty of its site, which is intersected by rivers and canals, and is compared by Europeans to Venice. This city is celebrated as an emporium of pleasure, and supplies the country with the choicest rope-dancers, jugglers, and the best actors; is famed for the beauty of its females; and is, in consequence, the residence of great numbers of the rich and voluptuous Chinese. The walls are more than four leagues in compass; and the suburbs extend along the canal, which is everywhere crowded with large barks, that afford a permanent residence to many of the inhabitants. It has an extensive manufacture of brocade and embroidery; and, from the continual bustle and crowds in the streets, it has the appearance of a great centre of trade. Long. 120. E. Lat. 31. 22. N.

SOUTH, one of the four cardinal points from which the winds blow.

SOUTH, Robert, an eminent divine, was the son of William South, a merchant of London, and was born at Hackney, near that city, in 1633. He was educated at Westminster school, and afterwards in Christ-Church College, Oxford. In 1654, he wrote a copy of Latin verses to congratulate Cromwell upon the peace concluded with the Dutch; and the next year a Latin poem, entitled *Musica Incantans*. In 1660, he was elected public orator of the university; and the following year became domestic chaplain to Edward earl of Clarendon, lord high chancellor of England. In 1663 he was installed prebendary of Westminster, admitted to the degree of D. D., and had a sinecure in Wales bestowed on him by his patron, the earl of Clarendon; after whose retirement into France in 1667, he became chaplain to the duke of York. In 1670 he was installed canon of Christ-Church; and in 1676 attended as chaplain to Laurence Hyde, Esq. ambassador extraordinary to the king of Poland. In 1678 he was presented to the rectory of Islip in Oxfordshire; and in 1680 rebuilt the chancel of that church, as he afterwards did the rectory-house belonging to it. After the revolution he took the oath of allegiance to King William and Queen Mary, though he excused himself from accepting a great dignity in the church, vacated by the personal refusal of that oath. His health began to decline several years before his death, which happened in 1716. He was interred in Westminster Abbey, where a monument is erected to his memory. He published, 1. *Animadversions on Dr Sherlock's Vindication of the Holy and ever Blessed Trinity*; 2. *A Defence of his Animadversions*; 3. *Sermons*, 8 vols. 8vo. And after his decease were published his *Opera Posthuma Latina*, and his posthumous English Works. Dr South was remarkable for his wit, which abounds in all his writings, and particularly in his sermons; but at the same time they equally abound in ill humour,

Sourera
||
South,
Robert.

¹ Raffles's History of Java, vol. i. p. 12.

South
Cape
||
South Sea.

spleen, and satire. He was remarkable for being a time-server. During the life of Cromwell he was a staunch Presbyterian, and then railed against the Independents; at the Restoration he exerted his pulpit-eloquence against the Presbyterians; and in the reign of Queen Anne was a warm advocate for Sacheverel.

SOUTH CAPE, at the southern extremity of New Holland. Long. 146. 56. E. Lat. 43. 47. S.

SOUTH-EAST ISLANDS, a group of islands, forming part of Recherche Archipelago, on the south coast of New Holland. Lat. 33. 53. S.

SOUTH ISLAND, a small island in the Eastern Seas, near the south-west coast of the island of Boutton. Long. 122. 50. E. Lat. 5. 42. S. This is also the name of a small island in the Indian Sea, near the eastern coast of Madagascar. Long. 50. 20. E. Lat. 17. S. There is another small island of this name near the south coast of the island of Celebes. Long. 120. 51. E. Lat. 5. 45. S.

SOUTH OF INDIA, a division of Hindustan, which is of a triangular figure, and has the Krishna river for its base, Cape Comorin the apex, while the sides are formed by the coasts of Coromandel and Malabar. It is 600 miles in length from Cape Comorin to the Krishna, and 500 miles in breadth where broadest. The great feature of this extensive region is the central table-land, from 3000 to 5000 feet above the level of the sea, separated by a wild, abrupt, and mountainous country, from the low plains to the east and west, which form a belt of small but unequal breadth between the hills and the sea. In this division of India may be seen the Hindu manners in their primitive simplicity, especially in Tinnevely and the adjacent districts. The Mahomedans are few in comparison with the native Hindus, over whom twenty centuries have passed without making any change in their habits. Southern India has suffered grievously from the devastations of war, and fully as much from the cruel extortion of its rulers. The territories comprehended in this division of the country are, a small portion of the Bejapoor province, the Balaghaut ceded districts; the Carnatic, Northern, Central, and Southern; Mysore, Canara, Malabar, Barramahal, Coimbatore, Dindigul, Salem and Kistnagherry, Cochin and Travancore; a detailed description of which will be found under their respective appellations.

SOUTH SEA, or *Pacific Ocean*, is that vast body of water interposed between Asia and America. It does not, however, strictly speaking, reach quite to the continent of Asia, excepting to the northward of the peninsula of Malacca; for the water interposed between the eastern coast of Africa and the peninsula just mentioned has the name of the *Indian Ocean*. The South Sea, then, is bounded on one side by the western coast of America, through its whole extent, from the unknown regions in the north to the Straits of Magellan and Terra del Fuego, where it communicates with the southern part of the Atlantic. On the other side, it is bounded by the coast of Asia, from the northern promontory of Tschukotskoi Noss, to the peninsula of Malacca already mentioned. Thence it is bounded to the southward by the northern coasts of Borneo, Celebes, Macassar, New Guinea, New Holland, and the other islands in that quarter, which divide it from the Indian Ocean. Then, washing the eastern coast of the great island of New Holland, it communicates with that vast body of water encompassing the whole southern part of the globe, and which has the general name of the *Southern Ocean*. Thus does this vast ocean occupy almost the semicircumference of the globe, reaching nearly from one pole to the other, and about the equatorial parts extending almost 180° in longitude, or 12,500 of our miles. The northern parts of the Pacific Ocean are entirely destitute of land, not a single island having yet been discovered in it from the latitude of 40° north and upwards, excepting such as are very near

the coast either of Asia or America; but in the southern part the islands are very numerous. See **POLYNESIA**.

SOUTH-WEST CAPE, on the south coast of New Holland, in the South Pacific Ocean, north-west of South Cape. Long. 146. 7. E. Lat. 43. 32. S.

SOUTH-WEST ISLES, a group of islands, seven in number, dependent on the Banda Islands. Kissier is the chief, which lies to the south-west of them all. They are low, and surrounded by shoals and rocks, and are inhabited by a ferocious and perfidious race, resembling those of New Guinea, who seem to have sprung from the Papuas or aborigines of that country, and the Caffres of Africa. They produce sandal-wood. The Dutch had a commercial establishment here. Population 36,266.

SOUTHAM, a small town of the hundred of Knightlow, in the county of Warwick, eighty-three miles from London. It has little or no trade. The inhabitants amounted in 1801 to 935, in 1811 to 1007, in 1821 to 1161, and in 1831 to 1256.

SOUTHAMPTON, a town of Hampshire, seventy-seven miles from London. It is finely situated at the junction of the river Test with the Itchen; these form an expanse of water, by which vessels may approach the town. It was anciently fortified, and the remains of its walls and castle still exist. It is one of the best-built towns of England. The High Street is broad and well paved. Southampton contains five parish churches, several alms-houses, a grammar school, some convenient bathing-houses, public rooms, and an elegant theatre. The borough was incorporated by Charles I., and is governed by a mayor, recorder, bailiffs, sheriff, and common-council men. It returns two members to parliament. It is in fact a county of itself, having its own magistrates, of whom the bishop of Winchester is one. This town has long been a place of great trade with Portugal, chiefly for the importation of port-wine and fruit. It has also some trade with France, with the islands of Guernsey, Jersey, Alderney, and especially with the Isle of Wight, to which place packet-boats are constantly sailing. The mildness of the air, the facility of making excursions by water as well as by land, the vicinity of the Isle of Wight and of New Forest, contribute to render the town a desirable place for either a temporary or a permanent residence, which is further recommended by the excellent supplies of fish, fruit, meat, and other necessities. The railway which connects Southampton with the metropolis will greatly tend to promote its prosperity. The inhabitants amounted in 1801 to 7629, in 1811 to 9258, in 1821 to 13,913, and in 1831 to 19,324.

SOUTHEND, a hamlet in the parish of Prittlewell, in the hundred of Rochford and county of Essex, forty-two miles from London. It stands at the mouth of the Thames, opposite to Sheerness; and from its easy communication with the metropolis, it has of late years been resorted to by considerable numbers for sea-bathing.

SOUTHERNE, THOMAS, an eminent dramatic writer, was born at Dublin in 1660, and received his education in Trinity College. He came young to London to study law; but instead of that, devoted himself to poetry and the writing of plays. His *Persian Prince*, or *Loyal Brother*, was introduced in 1682, when the Tory interest was triumphant in England; and the character of the Loyal Brother being intended to compliment James duke of York, he rewarded the author when he came to the throne with a commission in the army. On the Revolution taking place, he retired to his studies, and wrote several plays, from which he is supposed to have derived a very handsome subsistence, being the first who raised the advantage of play-writing to a second and third night. The most finished of all his plays are the *Fatal Marriage*, or the *Innocent Adultery*; and *Oroonoko*, or the *Royal Slave*, which is built on a true story related in one of Mrs Behn's novels.

South-west
Cape
||
Southerne,
Thomas.

South-
Moulton
||
Sozome-
nus.

Mr Southerne died in 1746, in the eighty-sixth year of his age; the latter part of which he spent in a peaceful serenity, having, by his commission as a soldier, and the profits of his dramatic works, acquired a handsome fortune, and being an exact economist, he improved what fortune he gained to the best advantage. He enjoyed the longest life of all our poets, and died the richest of them, a very few excepted. His plays are printed in three volumes 12mo. See the *Biographia Dramatica*, vol. i. p. 680.

SOUTH-MOULTON, a market-town, in the hundred of the same name, in the north part of the county of Devon, 179 miles from London, and twelve miles from Barnstaple. It stands on the river Moule, and contains many good houses, a large and handsome church, a commodious guild-hall, and a free grammar-school. The population amounted in 1821 to 3314, and in 1831 to 3826.

SOUTHWARK, a borough in the county of Surrey, but one of the suburbs of London, being only separated from it by the river Thames. The means of access have been greatly increased by a new bridge, and by the rebuilding of London Bridge. It contains six parishes, and, as to its police, is in a great degree under the control of the magistracy of the city. As it in fact forms a district of the capital, it is described under the head **LONDON**.

SOUTHWELL, a town of the hundred of Thurgarton, in the county of Nottingham, 139 miles from London. It is situated on a pleasing elevation above the plain watered by the river Trent. The parish church is collegiate, and well endowed, having sixteen prebendaries, besides choristers and singing boys. The chapter has jurisdiction over twenty-eight parishes. Its house was erected in 1377, and its library rebuilt in 1784. There are remains of an old palace belonging to the archbishops of York, with a beautiful walk on the north side of the church. There is a well-endowed and well-conducted free grammar-school, and a good market on Saturday. The inhabitants amounted in 1801 to 2305, in 1811 to 2674, in 1821 to 3051, and in 1831 to 3834.

SOUTHWOLD, a seaport town of the hundred of Blything, in the county of Suffolk, 105 miles from London. It is situated on the river Blythe. It is connected with the port of Yarmouth, but has a corporation of its own. The herring-fishery is extensively carried on in it, and of late years it has been resorted to for sea-bathing. The inhabitants amounted in 1821 to 1676, and in 1831 to 1875.

SOVEREIGN, in matters of government, is applied to the supreme magistrate or magistrates of an independent government or state; because their authority is only bounded by the laws of God and the laws of the state: such are kings, princes, &c.

SOVEREIGN POWER, or *Sovereignty*, is the power of making or sanctioning laws; for wherever that power resides, all others must conform to it, and be directed by it, whatever appearance the outward form and administration of the government may assume. For it is at any time in the option of the legislature to alter that form and administration by a new edict or rule, and to put the execution of the laws into whatever hands it pleases; and all the other powers of the state must obey the legislative power in the execution of their several functions, or else the constitution is at an end. In our constitution the law ascribes to the king the attribute of sovereignty; but that is to be understood in a qualified sense; that is, he is supreme magistrate, not sole legislator, as the legislative power is vested in the king, lords, and commons, not in any of the three estates alone.

SOZOMENUS, **HERMIAS**, an ecclesiastical historian of the fifth century, was born at Gaza or Bethelia, in Palestine. He was educated for the law, and became a pleader at Constantinople. He wrote an abridgment of Ecclesiastical History, in two books, from the ascension of our

Saviour to the year 323. This compendium is lost; but a continuation of it in nine books, written at greater length, down to the year 439, is still extant. He seems to have copied Socrates, who wrote a history of the same period. The style of Sozomenus is perhaps more elegant; but in other respects he falls far short of that writer, displaying throughout his whole book an amazing credulity, and a superstitious attachment to monks and the monastic life. His work, with those of Eusebius and Socrates, was published by R. Stephanus in 1544, by H. Valesius at Paris in 1668, and by Reading at Cambridge in 1720. All these editions are in folio. Several others have likewise appeared.

SPA, a town of the Netherlands, in the province of Liege and arrondissement of Verviers. It is one of the oldest, and was the most frequented, of the continental watering places. Its name has become generic for similar springs. It is situated in a narrow valley watered by a rapid and clear brook. The town consists of detached houses of all sizes, appropriate to the circumstances of the several classes of visitors.

The most remarkable waters are, 1. The Pouhon, situated in the middle of the town, which is more strongly impregnated with steel than the others; 2. The Sauveniere, a mile and a half east from it; 3. Groisbeck, near to the Sauveniere; 4. Tonnelet, situated a little to the left of the road which leads to the Sauveniere; 5. Geronstere, two miles south from Spa; 6. Wartroz, near to the Tonnelet; 7. Sarts or Niveset, in the district of Sarts; 8. Chevron or Bru, in the principality of Slavelot; 9. Couve; 10. Beverse; 11. Sige; 12. Geremont. These four last are near Malmedy.

Dr Brownrigg was the first person who discovered that carbonic acid gas forms a principal ingredient in the composition of the Spa waters, and actually separated a quantity of this elastic fluid, by exposing it to different degrees of heat from 110° to 170° of Fahrenheit. From twenty ounces seven drams and fourteen grains apothecaries' weight of the Pouhon water, he obtained eight ounces two drams and fifty grains.

The Spa waters are diuretic, and sometimes purgative. They exhilarate the spirits; and are more cooling, and allay thirst more effectually, than common water. They are found beneficial in cases of weakness and relaxation, either partial or universal; in nervous disorders; in obstructions of the liver and spleen; in cases where the blood is too thin and putrescent; in cases of excessive discharges proceeding from weakness; in the gravel and stone; and in most cases where a strengthening remedy is wanted. But they are hurtful in confirmed obstructions attended with fever, where there is no free outlet to the matter, as in ulcerations of the lungs. They are also injurious to bilious and plethoric constitutions, when used before the body is cooled by proper evacuations.

Spa was more fashionable formerly than it is at present. There are in it manufactures of iron, wood, and gilt toys. The resident inhabitants are about 3300.

SPACAFORNO, a city of the island of Sicily, in the province of Noto. It stands in a healthy situation on a hill, near the seaports of La Marza, and Santa Maria. It contains 8100 inhabitants, employed in various trades. Near to it is the Troglodyte town of Ispica, where the houses are excavated in calcareous rocks on both sides of a narrow valley.

SPAGIRIC ART, a name given by old authors to that species of chemistry which works on metals, and is employed in the search of the philosopher's stone.

SPAHIS, horsemen in the Ottoman army, chiefly raised in Asia. The great strength of the grand signior's army formerly consisted in the janisaries, who were the foot, and the spahis, who were the cavalry,

Spa
||
Spahis.

SPAIN.

History.

THE kingdoms of Spain and Portugal together form what is called the Pyrenean Peninsula, the most southerly, and at the same time the most westerly, portion of Europe. Except on the north-east, where it is connected with the rest of Europe by an isthmus about one hundred miles in breadth, this peninsula is wholly surrounded by the ocean. Spain, which occupies by far the greater part of it, has for its boundaries on the south and south-east the Mediterranean Sea; on the west, partly the long and narrow territory of Portugal, partly the Atlantic Ocean; on the north, the Bay of Biscay; and on the north-east the Pyrenees, a chain holding the second rank among the mountains of Europe, and forming a well-defined line of separation between France and Spain.

That the Peninsula was peopled at a very early period seems abundantly certain, but by whom it would be vain to inquire. The traditions which ascribe its colonization to Tubal, the grandson of Noah, may be allowed to repose undisturbed in the obscurity of the chronicles in which they are embodied. The earliest inhabitants whom history makes known to us were the Iberians, a race probably of Asiatic origin. At some period lost in the depths of antiquity, the Celts, amid their wide-spread migrations, penetrated into the Peninsula; but we are still ignorant how they entered the country, and whence they came, although these subjects have been matter of keen disputation. The two nations appear at first to have contended for the sovereignty of the soil, but finally to have amalgamated, to have shared the country between them, and, as a united people, to have assumed the compound name of Celtiberians. They were split into numerous tribes or clans, each of which occupied its own particular territory.

The delightful climate which Spain enjoys, the fertility of its soil, and the mines of gold, silver, and iron, by which it is enriched, proved powerful attractions to the Rhodians and Phœnicians, who established colonies in the country at a very early period. But the Carthaginians were the people who obtained the firmest footing in it. Availing themselves of the pretext of commerce, they frequented the coast of Cadiz, where they succeeded in erecting fortresses, dwelling-houses, temples, and buildings where business was transacted; and pushing their conquests into the interior as well as along the coast, they at length made themselves masters of the whole of Bætica or Andalusia, employing force when artifice failed. The Spaniards were roused to make resistance, but it was too late. Hamilcar, father of Hannibal, succeeded in overrunning a considerable part of the country, and bringing it, at least nominally, under subjection to Carthage, 238 years before the birth of Christ. He extended his conquests towards Murcia, Valencia, and Catalonia, in the latter of which provinces he founded the city of Barcelona. This conqueror having perished in a battle fought with some of the native tribes, was succeeded by his son-in-law Asdrubal, who built the port of New Carthage, now called Carthagená. The rapid strides which the Carthaginians had made towards the total subjugation of the Peninsula, aroused the fears of the Greek colonies situated on the coast of Catalonia and Valencia, and alarmed those tribes in the interior who still stoutly maintained their independence. Too weak to make head against Carthage themselves, they applied to the Romans for assistance. This great nation had long regarded with a jealous eye the growing prosperity of its rival Carthage, and eagerly embraced the cause of the discontented states. In the character of ally and protector, Rome sent a deputation to Carthage, and obtained from its senate two important con-

cessions; that the Carthaginians should not extend their conquests beyond the Ebro; and that they should not disturb the Saguntines and the other Greek colonies. But these conditions, although agreed to, did not correspond with the gigantic designs which Asdrubal had formed. The Romans, fully aware of the vast riches which the Carthaginians drew from Spain, and of the immense value of such a country to themselves in prosecuting their own ambitious schemes of foreign conquest, had entered into close alliance with some of the discontented tribes, no doubt with the ulterior view of subjecting them to their own domination. Saguntum, one of the most flourishing cities of the Peninsula, was one of these allies of Rome; and Asdrubal, in the prosecution of his design of subduing the whole of Spain before Rome could send succours to the confederates, collected a considerable force and marched against this city. On his way, however, he was assassinated by a slave; but the chief command passed into still abler hands, those of the renowned Hannibal. This famous Carthaginian was then in his twenty-fifth year, and greatly esteemed for his valour and his talents. After having conquered the kingdom of Toledo, he besieged Saguntum with his whole force, which is said to have amounted to 150,000 men. The Romans lost much time in fruitless attempts at negociation, and failed to send prompt succour to its faithful ally. The consequence was, that after a vigorous defence, the Saguntines were so reduced by hunger and fatigue, that they retired from the walls into the centre of the city, where they amassed all their valuable effects, and every thing combustible, into one vast pile. Placing their wives and children around it, they themselves issued from the gates and plunged sword in hand into the midst of the Carthaginians. The slaughter was prodigious on both sides, but in the end the Saguntines were cut off almost to a man. No sooner was their fate known in the city than their wives set fire to the pile, and precipitated themselves and their children into the devouring element. Thus perished Saguntum, one of the largest and most flourishing cities of Spain; and its destruction may be regarded as the opening of the second Punic war. Of the contests carried on between the Carthaginians and the Romans, till the final subjugation of the former, and the consequent incorporation of its territories with the Roman empire, an account will be found under the articles CARTHAGE and ROMAN HISTORY. We shall only in this place notice such leading events as are necessary to give clearness and connection to our narrative.

Two centuries were required by Rome to effect the total subjugation of Spain, that is, from the first invasion of the country by Cneus Cornelius Scipio in the year 218 B. C., till the last tribes, the Cantabrians and Asturians, laid down their arms to Augustus in the year 19 B. C. No other conquest had cost Rome so much. The numbers who perished in the field of battle, and the amount of treasure sacrificed, are not to be calculated. At the same time, scarcely any other acquisition was productive of so much advantage to the state, from the inexhaustible riches of the country. After the destruction of the Carthaginian power in Spain, this country was regarded as a Roman province, received the name of Hispania, and was divided by the senate into Citerior and Ulterior, or Hither and Farther; the Ebro serving as a boundary between the two. Each of these was governed by a prætor, annually appointed by Rome. The extortions of these functionaries very soon became so oppressive to the natives, that they at last resolved on attempting to rid themselves of their unprincipled rulers. Viria-

History.

History. thus, a native of Lusitania, the most remarkable man in the ancient history of Spain, collected a considerable body of malcontents, and took the field against the Romans. Not only by stratagems and sudden surprises, but in regular pitched battles, he succeeded in foiling the most valiant officers of the Roman legions. For above eleven years he bade defiance to the formidable hosts of the invader. To subdue him by force of arms was found impossible, and the base spirit of Q. Servilius Cæpio had recourse to treachery. The offer of a magnificent recompense stimulated three of the followers of Viriathus to assassinate him, which bloody deed they accomplished whilst he lay asleep. It is some consolation to record, that the murderers were disappointed of their reward, and dismissed from the Roman camp with insults and contempt. The indomitable spirit of independence which animated the Spaniards was not, however, broken by the death of their great leader. The Numantians, in particular, still remained fiercely hostile to the Romans, and the destruction of Numantia was decreed by the senate. Scipio Æmilianus, the conqueror of Carthage, was appointed to the command of the legions destined for this service, and the city was closely invested by a powerful army. While food was left to the besieged, they defied all the efforts of the Romans to take their city. Famine however humbled them into submission, and they sued for mercy, but in vain. Driven to desperation, the wretched remains of the defenders issued from the gates, and fell with fury upon the Roman intrenchments; but they were forced back within the walls. Æmilianus had formed the cruel resolution of starving them into an unconditional surrender. Rather than yield to this, the Numantians determined, in imitation of the Saguntines, to make a sacrifice of themselves, and of all that was valuable which they possessed. This resolution they carried into effect under circumstances even more shocking than those which accompanied the destruction of Saguntum. When the victor entered the city, not a human being remained alive to grace his triumph; nothing met his eyes but smouldering ruins and a horrible solitude. This event took place in the year 133 B. C.

After the destruction of Numantia, three fourths of the Peninsula submitted to Rome; and nothing very remarkable occurs in its history till the time of the civil war between Marius and Sylla. The latter having crushed the Marian faction, proscribed those who had taken a part in it, whom he could not immediately destroy. Among these was Sertorius, who had previously served in Spain as a tribune; a man of great bodily and mental endowments, of consummate valour, and experience in the art of war, but whose ambition was equal to his nobler gifts. Having escaped to Spain, he there succeeded in gaining over to his interest several of the native tribes, raised a considerable army, and routed the Roman legions in repeated engagements. He introduced a strict order of discipline among his troops, founded public schools, constituted a senate in imitation of that of Rome, and attempted to establish in Spain a rival sovereignty to that of Italy. But, in the midst of these brilliant though ambitious undertakings, Sertorius was basely assassinated by his subaltern Perpenna, in the year 73 B. C. With the death of this great captain expired the last faint glimmer of national independence. Pompey, and afterwards Julius Cæsar, reduced most of the native tribes to subjection. After the fall of Pompey in Africa, his eldest son selected Spain as the fittest scene for opposing the dreaded dictator. For the fourth time, Cæsar hastened to the Peninsula, and, on the plains of Munda, gained a bloody but decisive victory over the younger Pompey, who was slain in attempting to effect his escape from the country. Augustus, the successor of Cæsar, effectually secured the dominion of Rome over Spain, having reduced the Asturians, Galicians, and Cantabrians, the bravest and most warlike of the native tribes. Spain

History. now began to rest from the continual wars with which it had been devastated from the period of the Carthaginian conquest, and quietly submitted to the domination of Rome, from which it received its religion, its laws, its manners, and its language.

It has already been noticed that the country was at first divided into two provinces, Citerior and Ulterior, between which flowed the Ebro as the natural boundary. With the advance of the Romans the size of the provinces increased, but it is impossible to define their exact limits before the time of Augustus. This emperor, less desirous of effecting new conquests than of securing the old, made arrangements for improving the condition of the whole peninsula. Out of the two provinces he formed three, and gave them the names of Tarraco, Lusitania, and Bætica. Under the pretext of saving time and trouble to the senate, but really for the purpose of retaining power over the whole army in his own hands, he undertook the management of two of the provinces, in which, on account of the pretended insecurity of their situation, a considerable number of troops was maintained. Only Bætica came under the direct control of the senate. A proconsul, who had his seat at Hispalis, was installed governor of this province, but without any military power; whilst in the imperial provinces, a legatus Augustalis in Emerita, and a legatus proconsularis in Tarraco, exercised complete civil and military authority. Subsequently the province conceded to the senate fell entirely under the sway of the emperor, when the governor received the name of præses or president. The districts being very extensive, it was found necessary to appoint inferior officers; under the legate of Lusitania was placed a vice-legatus militaris, and there were three placed under the consular legates of Tarraco. A legate and a quæstor were subject to the proconsul of Bætica. In this manner the country as a whole was divided. Let us now take a glance of the constitution and condition of the towns.

After the complete subjugation of the Peninsula, the cohorts, composed principally of the natives of the country, were transplanted to the most distant parts of the empire, while Roman legions were sent into Spain to supply their place. No arrangement could have been made that was better calculated to give a Roman impress to the character of the people, and to their manners, customs, and establishments. In the interior of the country, towns purely Roman sprung up, small tracts of country having been conferred on soldiers as a reward for their services. Thus the town of Leon is indebted for its name and origin to the seventh legion, which settled there; and in the same manner arose Emerita Augusta (Merida), Pax Julia (Beja), Cæsar Augusta (Saragossa), and many others. Originally, most of the cities managed their own affairs; but when Caracalla declared all his subjects throughout his vast empire Roman citizens, the constitutions of the cities of Spain were made uniform with those of the other cities of the empire. Rome, the capital, was the great type to which they all conformed. For purposes of general police, and for the superintendence of public works, fortresses, entertainments, and the like, ædiles were appointed in provincial towns, whose office, however, was one more of pomp and honour than emolument. The affairs of the cities were universally administered by a council or curia, the members of which, called *decuriones*, were chosen from among the richest and most respectable of the inhabitants. As advocates or defenders of the people, there were the *defensores civitatum*, who neither belonged to the body of the decurions nor to the army, but formed rather a sort of check upon these, and resisted the encroachments of power on the rights of the citizens. We pass over a number of other subordinate functionaries, whose duties are either imperfectly known, or, where known, of minor importance.

All matters not cognizable by the legal tribunals, nor af-

History. fecting the interest of the emperor, were discussed in the assembly of the decurions. For all important affairs, such as those affecting the welfare of the whole district, the decurions of the principal city of a province could call a general assembly, *concilium*, to which the other towns sent plenipotentiaries. Long after the comitia had ceased to exist in Rome, the province enjoyed the privilege of calling together such meetings; and they served at the same time as a means of making known their wants to the emperor.

Of all the provinces incorporated with the Roman empire, there was not one productive of so much gain, not one in which such inexhaustible sources of wealth were discovered, as the Pyrenean Peninsula. Mines, rich in the precious metals,¹ satisfied the thirst of the Romans for gold; and a soil nowhere surpassed in productiveness filled their granaries with corn. During the republic the Peninsula was laid under the obligation of supplying the capital of the empire with the twentieth part of its corn harvests. The price paid for the grain was fixed by the Roman senate itself, a convenient way of obtaining cheap provisions.

While Spain continued to be ravaged by war, the Romans did not in general bind themselves to a regular system of taxation, but only drew as much from the Peninsula as it was convenient for it to pay at the time; but when the conquest of the country was completed, a fixed rate of taxation was introduced. Consequently, after Augustus had divided Spain in the manner which we have described, the senate sent quæstors into the provinces to collect the taxes. In those provinces placed under the immediate control of the emperor, there were procurators employed; and functionaries of this class were also appointed to look after the monies received by the officers of the senate, the application of the whole being under the entire management of the emperor. These procurators were likewise extremely useful in preventing the subordinates from defrauding the emperor. By degrees their number increased, so that ultimately there came to be procurators, not only for the collective income of a province, but for separate branches of the taxes.

In Spain, as well as throughout the whole Roman empire, the taxes consisted of a capitation and a land tax; but by degrees, more from the extravagance of the emperors than from the necessities of the state, the people came to be burdened with a multitude of other imposts. The towns had their own particular estates and incomes, independent of those of the government, and which were managed by the civic authorities themselves. These served to defray the expenses of erecting public establishments, building fortresses, and instituting games. The contribution to the state taxes paid by the towns was levied by the magistrates from the inhabitants, in exact proportion to their wealth; hence the taxes, although they continued to rise, did not press with unequal and crushing weight upon individuals and classes. Never was Spain so wealthy, so populous, and so industrious, as during the first centuries of the empire. Aqueducts, bridges, amphitheatres, and other magnificent structures, even the ruins of some of which posterity surveys with wonder, still bear testimony to the flourishing condition of the country during that period.

When Constantine the Great assumed the purple, important changes were introduced into the empire. From the province of Tarraco he separated the governments of Carthage and Galicia, thus making five provinces in the Peninsula, viz. Tarraco, Carthage, Galicia, Lusitania, and Bætica. Theodosius the Great erected the Balearic Isles into a province, and the African district of Tingitania was also reckoned another, so that there were seven in all. The principal cities of these provinces were as fol-

History. low: of Bætica, Hispalis; of Lusitania, Emerita; of Galicia, Bracara; of Tarraco, Cæsar Augusta; of Carthage, New Carthage; of the Balearic Isles, Palma; and of Tingitania, Tingis. The first three were placed under consuls, and the others under presidents (*præsides*). Spain was subject to the prefecture of Gaul, and over these local governors was placed a vicar (*vicarius*), whose administration was chiefly confined to civil affairs, and the count (*comes*), whose functions were of a military nature. Sometimes, however, both the civil and military departments fell to the vicar. We have yet to mention one important event connected with the Roman conquest of Spain, namely, the introduction of Christianity into the Peninsula. This took place so early that the unanimous voice of tradition has ascribed it to St James the elder; and from the same authority we also learn that St Paul preached "Christ crucified" to the idolaters of Spain. Of course little or no reliance is to be placed on such statements; but whether the apostles or their successors propagated the gospel in these regions, certain it is that Spain can adduce her martyrs as early as the second century. There is abundant evidence to prove the antiquity of the persecutions sustained by the Christians of Spain, but our limits prevent us from entering into details.

The prosperity of the Peninsula began to decline after the death of Constantine, A. D. 337. A species of tax introduced by Diocletian, which was made to fall with paralyzing weight on the middle or industrious classes, proved so pernicious in its operation, that in a short time the country presented the melancholy picture of deserted towns, fields lying waste, fruit-trees uprooted from the soil, that the possessors of the ground might lessen the value of their property, and thus escape the taxes; trade and manufactures at a stand; in short, nothing but desolation, poverty, and misery, everywhere presented themselves. It only required a strong impulse from without to overwhelm the whole country in ruins. The last day of the year 406 marks the passage of the Vandals, Alans, Suevi, and other Germanic tribes, across the Rhine. From this river to the Pyrenees, terror and dismay announced their approach, death and destruction marked their progress. For a time this great barrier of nature and of nations restrained the roving bands, and the mountain-passes were at first well guarded. But the prolific fields and wealthy mines of Spain were too rich a prey not to be reached at all hazards. Finding an opportunity, when negligence had weakened the line of defence (409), they burst like a torrent through the Pyrenean chain, and poured the tide of destruction from its base to the Pillars of Hercules. Native historians of the Peninsula describe the ravages committed by these barbarians as dreadful and revolting almost beyond parallel. The very wild beasts quitted their lairs to prey upon the human species, too emaciated by famine and pestilence to drive them back. In a word, the country was turned into a desert; and, satiated with carnage and rapine, the barbarians sat down amidst its ruins and divided it by lot. Bætica fell to the Vandals, Lusitania to the Alans, and Galicia, with a great portion of Leon and Castille, to the Suevi. Tarraco alone seems still to have been retained by the Romans.

But a fourth people, more formidable than all the rest combined, came to disturb the new settlers in their possessions. These were the Goths under Ataulphus, to whom Honorius, the Roman emperor, had ceded the fertile provinces of Southern Gaul and the Peninsula. The Gothic monarch espoused Placidia, the emperor's sister, in 414, and immediately proceeded to Barcelona, where, however, he was shortly afterwards assassinated. His successor, Sigeric, a detestable monster, shared the same fate; and the election of the Goths now fell upon Wallia, a chief every way

¹ Gibbon very justly observes, "Spain, by a very singular fatality, was the Peru and Mexico of the old world. The discovery of the rich western continent by the Phœnicians, and the oppression of the simple natives, who were compelled to labour in their mines for the benefit of strangers, form an exact type of the more recent history of Spanish America." Chap. vi.

History. worthy of their choice. Peace being made with Rome, hostilities were vigorously commenced against the kindred barbarians (418). The result of the war was the subjugation of the Suevi, the total destruction of the Alans, and the expulsion of the Vandals from Spain (427). But the restless and powerful Suevi were scotched, not killed. During the reign of Theodoric, Wallia's successor, they became formidable alike to the Romans and the Goths, and made many important conquests in the neighbouring provinces. Theodoric might easily have subdued them had he not been summoned to encounter a far more terrible antagonist, the renowned Attila, with his half million of mounted Huns. The death of the Gothic monarch on the plains of Chalons (451), the elevation of his son Thorismund to the vacant throne, his assassination by his brothers, and the elevation of the elder of the fratricides, Theodoric, were events which closely followed each other. The reign of the last-named prince was diversified by alternate success and disaster. The Peninsula, become one great battlefield to three contending hosts, the Goths, Romans, and Suevi, was plunged in misery, and, from the Pyrenees to the sea of Africa, was overspread with innumerable swarms, which, like so many locusts, utterly destroyed the spots on which they settled. While Theodoric was preparing to conduct an army across the Pyrenees against Remismund, king of the Suevi, he was assassinated by his brother Euric, in his capital of Toulouse (466).

The reign of Euric was unusually brilliant and successful. He rendered himself absolute lord of the country, by extinguishing the dominion of Rome in it, and completely subjecting the Suevi. Euric was the first legislator of his nation, and the founder of the Gothic kingdom of Spain; for hitherto the country had rather been overrun than subdued. This prince died at Arles, the capital of his empire, A. D. 483. He was succeeded by his son Alaric, a weak sovereign, who, after submitting pusillanimously to many indignities, was overthrown in battle, and slain by Clovis, king of the Franks (506). Amalaric, the son of Alaric, being a minor, was for a time superseded by his natural brother Gensaleic, but ultimately ascended the throne (522). He was the first Gothic king who established his court in Spain. He fixed on the city of Seville. From the death of this prince (531) till Recared I. became king of the Goths (587), a few obscure royal names occur, regarding whom it would be a mere waste of space to enter into details. The chief act of this sovereign was to reclaim his subjects from the heresy of Arianism to orthodox Catholicism. He died in 601. Of eleven monarchs who followed, occupying a period of seventy years, none is in any way remarkable. In 673, Wamba, a man distinguished alike for wisdom, valour, and virtue, was raised, by the unanimous voice of the Gothic electors, to the throne, left vacant by the death of Receswind (672). The early part of his reign was spent in quelling intestine war. During the latter part of it he successfully cultivated the arts of peace, and built a fleet for the protection of the coast; a very wise precaution, for the Saracens had already begun to swarm all over the sea of Africa. Had Wamba been succeeded by monarchs of equal prudence and activity, the scourge of Saracenic domination, the greatest perhaps that ever afflicted any people, would probably have been for ever averted from Spain. In consequence of having sunk into a death-like trance, in which state he was apparelled in the garments of the grave, Wamba was compelled to relinquish the crown (680).

One of the most celebrated names in the line of Gothic princes is that of Roderick, who ascended the throne in 709. He owed his elevation to a party which rose against his predecessor Witiza, whose two sons, with their relations, Count Julian, governor of the Gothic possessions in Africa, and Oppas, an archbishop, are supposed to have aided the

History. Saracens in their design of conquering the Peninsula. At all events, the party which they formed against Roderick weakened the Gothic monarchy, and thus gave encouragement to the Moors to make a descent on the country, which they effected in 711. Roderick marshalled a large army, amounting, it is said, to 90,000 men, and advanced against the audacious infidel. The hosts met upon the plains of Xeres, where was fought a battle, so bravely contested on either side that it seems scarcely unworthy to have decided the fate of a kingdom. For three days, from sunrise to sunset, the embattled squadrons fought with equal ardour and obstinacy, till victory at last declared for the Mahomedans. Roderick himself is believed to have perished in the conflict, as he was never heard of more. By this decisive battle the Moors made themselves masters of nearly the whole of Spain. The wretched remains of the Goths retired into the mountainous parts of Asturias, Burgos, and Biscay, where they maintained their independence, and perpetuated their monarchy. In a few years their power began to revive under the renowned Pelagio or Pelayo, a prince of the royal blood. But before noticing the exploits of this warrior, we shall take a brief view of the political, civil, and religious condition of the people subject to the Gothic monarchy.

The local divisions of Spain, as already laid down, underwent little or no change until some time after the descent of the Mahomedans. The power possessed by the Gothic kings was considerable; but its exercise was greatly controlled by the nobles, in general a fierce, turbulent, and haughty body. The jurisdiction of the monarch was not confined to affairs purely temporal. He nominated bishops, presided, if he chose, at ecclesiastical tribunals, convoked national councils, and regulated the discipline of the church. Next to the king in civil dignity were the dukes, who appear to have been governors of provinces. After them came the counts, whose jurisdiction is supposed to have been confined to particular cities. A number of other functionaries were subordinate to these; and besides the officers of the crown, each city or town had its municipal council. Of course there were regular courts of law instituted throughout the country, where justice was administered; the forms of procedure in these tribunals being much the same as those practised in the Spanish courts at the present day, but less tedious. There was a Visigoth code of laws, partly of Gothic, partly of Roman origin. If we pass from the civil to the military state of the country, we find that the Goths were a nation of soldiers, the obligation of service being imperative on all freemen. After the Gothic power was established in Spain, the constitution of the church underwent important changes. The pope was acknowledged as supreme head, and metropolitan sees were formed, which exercised an ecclesiastical jurisdiction over the suffragan bishops. The bishops possessed an irresponsible power over the rectors, displacing or removing them at pleasure. The cathedrals and parish churches were in general well endowed; lay patronage existed, and monasteries were introduced. As in other countries, the ecclesiastical councils were of a threefold description, diocesan, provincial, and national, convoked respectively by the bishop, the metropolitan, and the king. The Goths present nothing of literature worthy of particular notice. If we pass to the domestic arts, we find still less to admire; in every thing they consulted the useful in preference to the beautiful or magnificent. It is therefore to be concluded, that however devout, temperate, honest, and sincere the Goths might have been, as many historians attest, yet Spain under their dominion made little advancement in civilization and the elegant arts.

The Moors under Tarik and Musa subdued the fairest portion of Spain, including the largest and strongest cities of the kingdom, with a rapidity which shows how complete-

History. ly the power of the Goths was broken. Still many of them preferred independence under severe privations amidst the wild rocks of the Asturias, to abundance and plenty on the fertile plains of Murcia. At the head of those who sought a refuge in this mountain sanctuary was Pelayo, a prince of royal Gothic blood, and who is recognised by Spanish historians as having acceded to the throne in 718; Theodomir, the legitimate monarch, having ingloriously submitted to the yoke of the infidel. Numbers of his countrymen flocked to his standard, and his force became at length so formidable as to create alarm in the Saracens. A large army was despatched to the Asturias to crush the rising insurrection; but in attempting to gain the position where Pelayo and his resolute followers were strongly posted, the Moors were repulsed with a slaughter so terrible, that for some years they showed no inclination to assail their formidable neighbours. Various successes followed, and the Asturias, now left in the undisturbed possession of Pelayo and his band, became the asylum of the liberty and the religion of the Christians in Spain. It formed the nucleus of a kingdom, which was destined slowly but surely to increase in size from century to century, until the invaders were finally expelled from the Peninsula. Little more is known of Pelayo, than that he gained repeated victories over the Moors, and died in peace in 737. He was succeeded by his son Favila, whose reign was brief and his end tragical, he having been killed by a wild boar in 739. The subsequent history of Spain is rendered so confused by the numerous kingdoms established by Christians and Moors, that some chronological guide is necessary to render it intelligible. We shall therefore present a chronological list of the various sovereigns who reigned over different parts of the country, which had been erected into distinct and independent sovereignties. The dates given mark the years in which the sovereigns acceded to the throne; the intervening periods, of course, indicate the duration of their respective reigns. We shall commence with the Mahommedan succession, as during the earlier centuries the greater part of Spain was subject to the Moors.

MAHOMMEDAN RULERS OF SPAIN.—CORDOVA.

1. *Emirs*.—Tarik ben Zeyad and Musa ben Nozeir, 711. Abdelasis ben Musa, 714. Ayub ben Habib and Alhaur ben Abderahman, 715. Alsama ben Melic, 721. Abderahman ben Abdalla, 722. Ambisa ben Sohim, 724. Hodeira ben Abdalla and Yahia ben Zulema, 726. Othman ben Abi Neza, Hodeira ben Alhaus, and Alhaitam ben Obeid, 727. Mohammed ben Abdalla, 728. Abderahman ben Abdalla (second time), 729. Abdelmelic ben Cotan, 733. Ocba ben Albegag, 736. Abdelmelic ben Cotan again, 741. Baleb ben Bakir, and Thalaba ben Sulema, 742. Husam ben Dhizar, 743. Thueba el Ameli, 744. Yussuf el Fehri, 746.

2. *Kings*.—Abderahman I. ben Moawia, 755. Hixem I. Abderahman, 787. Alhakem ben Hixem, 796. Abderahman II. ben Alhakem, 821. Mohammed I. ben Abderahman, 852. Almonahir ben Mohammed, 886. Abdalla, brother of the former, 888. Abderahman III. grandson of Abdalla, 912. Alhakem, II. son of Abderahman III. 961. Hixem II. ben Alhakem II., dethroned to make way for his cousin Mohammed, but restored in 1010; in 1012 finally removed, 976. Suleyman, 1012. Ali ben Hamud, 1015. Abderahman IV. 1017. Alcaassim ben Hamud, brother of Ali, 1018. Abderahman V., and Mohammed II. cousin of Hixem II., 1023. Hixem III. brother of Abderahman IV. 1026. Gewahr ben Mohammed, 1031. Mohammed ben Gewahr, 1044. Mohammed Almoateded, 1060. Mohammed Almosstadir, 1069. *Dynasty of the Almoravides*.—Yussef ben Taxfin, 1094. Ali ben Yussef, 1107. Taxfin ben Ali, 1144. *Dynasty of the Almohades*.—Abdelmumen, 1147.

Yussef Abu Yacub, son of Abdelmumen, 1163. Yacub ben Yussef, 1178. Mohammed, son of Yacub, 1199. Abu Yacub, 1213. Abulmelic, and Abdelwahid son of Yacub, 1223. Almamon and Abu Ali, 1225.

KINGDOM OF GRANADA.

Mohammed I. Aben Alhamar, founder of the kingdom, 1238. Mohammed II. ben Mohammed, 1273. Mohammed III. Abu Abdalla, 1302. Nassir Abul Giux, brother of the preceding, 1309. Ismail ben Ferag, nephew of Nassir, 1313. Mohammed IV. ben Ismail, 1325. Yussef Abul Hagiag, brother of the former, 1333. Mohammed V. ben Yussef, 1354. Ismail II. brother of Mohammed, 1359. Abu Said, brother-in-law of Ismail II. 1360. Yussef II. Abu Abdalla, son of Mohammed V. 1391. Mohammed VI. son of Yussef II. 1396. Yussef, brother of Mohammed VI. 1408. Muley Mohammed VII. son of Yussef III. 1423. Mohammed VIII. cousin of Muley Mohammed VII. 1427. Mohammed VII. restored, 1429. Yussef IV. Aben Alhamar. Mohammed VII. restored a second time, 1432. Mohammed IX. Aben Osmin (nephew of Mohammed VII.), 1445. Mohammed X. nephew of Mohammed VII. 1454. Muley Ali Abul Hassan, son of Mohammed X. 1463. Abu Abdalla, son of Abul Hassan, 1483. Abdalla el Zagal, brother of Abul Hassan, 1484. Both princes survived the fall of Granada, which took place in 1491.

KINGDOM OF THE ASTURIAS AND LEON.

Pelayo, 718. Favila, son of Pelayo, 737. Alfonso, son-in-law of Pelayo, 739. Fruela I. son of Alfonso, 757. Aurelio, nephew of Alfonso, 768. Mauregato, bastard of Alfonso, 774. Bermudo I. nephew of Alfonso, 788. Alfonso II. son of Fruela, 791. Ramiro I. son of Bermudo, 842. Ordoño I. son of Ramiro, 850. Alfonso III. son of Ordoño, 866. Garcia, son of Alfonso III. 910. Ordoño II. brother of Garcia, 914. Fruela II. son of Alfonso III. 923. Alfonso IV. son of Ordoño II. 925. Ramiro II. brother of the same Alfonso, 930. Ordoño III. son of Ramiro II. 950. Sancho I. brother of the same Ordoño, 955. Ramiro III. son of Sancho I. 967. Bermudo II. grandson of Fruela II. 982. Alfonso V. son of Bermudo II. 999. Bermudo III. son of Alfonso V. 1027. With this sovereign the male line of the house of Leon terminated. Leon and Castille now formed separate kingdoms, the contemporaneous sovereigns of which were:—

LEON.

- 1037. Fernando I. king of Castille; king of Leon in right of his wife.
- 1065. Alfonso VI. son of Ferdinando I.
- 1126. Alfonso VIII. (the emperor), son of Urraca.
- 1157. Fernando II. son of Alfonso the emperor.
- 1188. Alfonso IX. son of Ferdinando II.
- 1230. Ferdinando III. son of Alfonso IX. (also king of Castille).

CASTILLE.

- 1026. Sancho el Mayor, king of Navarre; first king of Castille in right of his wife.
- 1035. Fernando I. son of Sancho.
- 1065. Sancho II. son of Ferdinando I.
- 1072. Alfonso I. son of Ferdinando I. (also VI. of Leon).
- 1109. Urraca, daughter of Ferdinando I., and Alfonso VII. (also sovereign of Leon).
- 1126. Alfonso II. (the emperor), son of Urraca.
- 1157. Sancho III. son of Alfonso the emperor.
- 1158. Alfonso III. son of Sancho III.
- 1214. Enrique I. son of Alfonso III.
- 1217. Fernando III. son of Alfonso IX. of Leon (afterwards king of Leon).

History.

KINGDOM OF LEON AND CASTILLE UNITED.

Alfonso X. son of Fernando III. 1252. Sancho IV. son of Alfonso X. 1284. Ferdinando IV. son of Sancho IV. 1295. Alfonso XI. son of Ferdinando IV. 1312. Pedro the Cruel, son of Alfonso XI. 1350. Enrique II. bastard son of Alfonso XI. 1369. Juan I. son of the former, 1379. Enrique III. son of the former, 1390. Juan II. son of the former, 1406. Enrique IV. son of the former, 1454. Isabel, daughter of Juan II. and her husband Ferdinando V. (the II. of Aragon), 1474. Juana, daughter of Fernando and Isabel, and Philip I. of Austria, 1504.

KINGDOM OF NAVARRE.

The first independent count of Navarre was Sancho Inigo, 873. The kings reported to have reigned prior to this period are entirely fabulous. Garcia I. (Iniguez), son of Count Sancho, and the first king, 885. Sancho I. (Garces Abarca), son of Garcia I. 905. Garcia II. (el Trembloso), son of Sancho I. 924. Sancho II. (el Mayor), son or grandson of Garcia II. 970. Garcia III. son of Sancho, 1035. Sancho III. son of Garcia III. 1054. Sancho IV. (also I. of Aragon), 1076. Pedro I. son of Sancho IV. (also king of Aragon), 1094. Alfonso I. brother of Pedro (also king of Aragon), 1104. Garcia IV. 1134. Sancho V. son of Garcia IV. 1150. Sancho VI. son of Sancho V. 1194. Thibault I. nephew of Sancho VI. 1234. Thibault II. son of the former, 1253. Henri, in right of his wife, who was daughter of Thibault II. 1270. Jeanne, queen of Philip IV. king of France, 1274. Louis Hutin (king of France), son of Jeanne, 1305. Philip, brother of Louis (also king of France), 1316. Charles I. brother of Philip (also king of France), 1322. Jeanne II. daughter of Louis Hutin, married to Philip count of Evreux, 1328. Charles II. son of Jeanne, 1349. Charles III. son of the former, 1387. Blanche, daughter of Charles III. and Juan her husband, son of Ferdinando I. king of Aragon, 1425. François Phœbus de Foix, in right of his grandmother, daughter of Juan, 1479. Catherine de Foix, sister of Phœbus, and her husband, Jean d'Albret, 1483. This kingdom united with Castille in 1512.

KINGDOM OF ARAGON.

Aragonese independence is to be dated from 1035, when Sancho el Mayor, king of Navarre and Castille, divided his states among his sons. Aragon fell to the lot of Ramiro I. 1035. Sancho I. (afterwards IV. of Navarre), son of Ramiro I. 1063. Pedro I. son of Sancho I. (also king of Navarre), 1094. Alfonso I. brother of Pedro (also king of Navarre), 1104. Ramiro II. brother of Alfonso, 1134. Petronilla, daughter of Ramiro II. 1137. Alfonso II. son of Petronilla, 1163. Pedro II. son of Alfonso II. 1196. Jayme I. son of Pedro II. 1213. Pedro III. son of Jayme I. 1276. Alfonso III. son of Pedro III. 1285. Jayme II. brother of Alfonso, 1291. Alfonso IV. son of Jayme II. 1327. Pedro IV. son of Alfonso IV. 1336. Juan I. son of Pedro IV. 1387. Martin, brother of Juan I. 1395. Fernando I. brother of Enrique III. king of Castille, elected 1412. Alfonso V. son of Ferdinando I. 1416. Juan II. (also king of Navarre), brother of Alfonso V. 1458. Fernando II. (the V. of Castille), son of Juan II. 1497. This kingdom united with Castille in 1516.

COUNTS OF BARCELONA.

During the early period of Mahommedan domination in Spain, Barcelona and all Catalonia were subject to it. In the year 801, however, the Moors were expelled from Barcelona, and a count named Bera, a native of Gothic Gaul,

History. was nominated head of the independency. The names of his successors, eleven in number, are too insignificant to require mention individually. Alfonso Raymond, the last count, acceded to power in 1131. On his death, Barcelona was united with Aragon.

To give a connected history of these various sovereignties is quite incompatible with our limits. We can only briefly describe those more important transactions affecting the whole country, in which the Christians, by wresting portions of soil from the Moors, compelled them to retire within narrower limits, and thus circumscribed their power. Alfonso and Fruela, the sovereigns who immediately succeeded Pelayo's son, inflicted several severe blows on the Moors, and overran a considerable portion of the flat country. But what proved a more effectual check upon the Saracens than the arms of the Christians, were their own domestic quarrels. So mutable had been the government, that in the space of only forty years from the period of their first landing in Spain, no less than twenty emirs had been called, or had raised themselves, to the seat of power. On the establishment of a monarchy under Abderrahman, intestine revolt was quelled for a time; but a more formidable foe from without made his appearance. This was no other than the celebrated Charlemagne, who poured his legions over the Pyrenees into the valleys of Catalonia. We shall not discuss the much agitated question as to the motives which brought this emperor into Spain. He appears to have received an invitation from some discontented Moorish governors; and in acceding to their request, he probably also listened to the dictates of his own ambition. Certain it is that he entered Spain with a powerful army, and, if we can trust his historian Eginhard, subjected the country from the Pyrenees to the Iberus. But he was soon recalled from the Peninsula by the revolt of the Saxons. In his passage through the mountain defiles, the rear of his army was attacked by the Navarrese, and cut to pieces.

It seems certain, that from the period when Charlemagne poured his legions into Navarre, he considered the country as a fief of his crown, and thus gave great umbrage to the Asturian kings. But the inhabitants of the province, averse to the sway of either, longed for independence, and this they succeeded in achieving about the year 885. The rise of this kingdom was another blow to the Saracens. So signal were the successes gained over them by the Christians of Navarre, that in the year 920 not a Mahommedan remained in the whole kingdom north of the Ebro. The kings of Asturias and Leon also rapidly extended their dominions. Ordoño II. invaded the Mahommedan possessions, and gained many advantages. In 932, Ramiro II. made an irruption into the states of the enemy, and ruined Madrid. Arabian writers boast of terrible reprisals having been made on the Christians, and assert that Ramiro himself was defeated. The Saracens having invested Zamora, Ramiro approached with a formidable army. The combatants met, and a battle ensued, more obstinately contested and bloody than any that had been fought since the days of Roderick. There can be no doubt that victory shone on the banners of the Christians, but the success was less splendid than their writers assert it to be. The accounts of all the battles fought between the Moors and the Christians in Spain are to be received with caution. The Arabian writers, to exalt the prowess of their countrymen, exaggerate mere skirmishes into great battles, and temporary and partial checks into decisive victories. In equivocal cases, they seem invariably to claim the advantage; and where they were defeated, they either obscurely hint the fact, or diminish the loss which they sustained. It is to be feared, that in many instances Christian chroniclers are chargeable with similar partiality.

History.

The reign of Abderahman III. (912) has been extolled as the most brilliant period in the history of the Spanish Arabs. Commerce flourished, and riches were accumulated to an unexampled extent. A powerful navy was formed, and maintained in full activity; the arts and sciences were cultivated with ardour, because their professors were rewarded with princely liberality; many splendid works were undertaken in the towns of Mahomedan Spain; and the king himself was the friend of industry and of merit. Still none of the territories which had been lost in previous reigns was recovered, and the Christians were gradually becoming more and more formidable to the Moors, when Mohammed, better known as Almanzor, appeared to restore the glory of the Saracen arms. He was an eminent general, an enlightened statesman, and a patron of the liberal arts. His campaigns against the Christians proved most fatal to them. The towns were ruined, the open country was ravaged, and once more the mountains of Asturias became the inaccessible asylum of the native monarchy. At length the three powers, Navarre, Castille, and Leon, entered into a confederacy to repel the common foe. The armies met at a place situated between Soria and Medina Celi, where a drawn battle was fought. This check, and the fearful loss which he had sustained, so mortified Almanzor, that he sunk under the weight of his despair, and died, some assert by voluntary abstinence from food, in the year 1001. An event of some importance to the Christian cause was the erection of Castille into a distinct kingdom, by Sancho el Mayor, king of Navarre, the most powerful prince of his age and country. Besides Sobrarve, he held the lordship of Aragon; and in 1026, in right of his wife, a princess of Castille, he became king of that country. By his conquests he considerably extended his dominions; and the marriage of his son Fernando to the heiress of Leon gave him influence in the affairs of that kingdom; so that at the period of his death, in 1035, he was virtually master of all Christian Spain except Catalonia. Before his death he divided his states among his sons, and Aragon fell to the share of Ramiro. The independence of Aragon as a separate kingdom is therefore to be dated from 1035, the year in which Ramiro I. obtained possession of the throne.

About the middle of the eleventh century Spain may be said to have been divided into two unequal parts, by a straight line drawn from east to west, from the coasts of Valencia to a little below the mouth of the Duero. The country north of this belonged to the Christians, who as yet had the smallest and least valuable portion, while all the rest belonged to the Moors. In point of wealth and real power, both by land and sea, the latter were much superior to the former; but their perpetual dissensions materially weakened them, and every day facilitated the progress of the Christians. Indeed, had either party been united, the other must soon have been quelled; but the Christians, although they did not constantly make war upon each other like the Moors, continued from time to time to be so embroiled by domestic feuds, as to be unprepared for striking a decisive blow with the combined armies of all the kingdoms; while the same evils, existing to a still greater extent amongst the Mahomedans, rendered it impossible for their monarchs to take advantage of the untoward state of the affairs of the Christians. Among the Moors almost every city was a kingdom; and as these petty sovereignties supported one another very indifferently, they, one after another, fell a prey to their enemies. The rapidity with which the kingdom of Cordova fell to pieces has few examples in history. Alfonso I. king of Aragon, also of Navarre, and for some time of Castille and Leon, is reckoned among the most valiant princes of Spain. From his warlike habits he was surnamed *El Batallador*. He conquered Tudela, Saragossa, Tarragona, Calatayud, Daroca, Mequinencia, and much of the country south of the Ebro. Since the con-

quest by the Arabs, he was the first who carried the Christian ensigns into Andalusia. In 1134, however, he lost a great battle, and either perished in the conflict or died of grief shortly afterwards. This was a misfortune, but the misfortunes of the Christians were in general soon repaired, although for nearly a century their conquests were less brilliant than those achieved by *El Batallador*. At the commencement of the thirteenth century, indeed, the Moors gained some decided advantages, and reduced several important towns. But the balance was restored on the celebrated plains of Tolosa, where an enormous army of Moors from Africa was nearly annihilated. Alfonso of Castille having made some destructive inroads into Andalusia, Mohammed Abu Abdalla, emperor of Barbary, prepared to punish his audacity. It is related, on credible authority, that one of the five divisions of the army which he assembled mustered 160,000 combatants. To meet this overwhelming host, the Christian kings, fortunately at this juncture brought to terms of amity with one another, united their armies at Toledo, where they were joined by numerous volunteers from Portugal and France. On the 16th of July 1212 the Christian army descended the mountainous chain which divides New Castille from Andalusia into the plains of Tolosa, where the Mahomedan army was drawn up in battle array. The conflict which ensued was obstinate and bloody, but victory at length declared for the Christians, and its immediate consequences involved the ruin of the Mahomedan empire in Spain. The thirteenth century is distinguished by other important advantages gained by the Christians. Ferdinand III. king of Leon, afterwards of Castille, by his numerous victories made himself lord of Spain, from the Bay of Biscay to the vicinity of the Guadalquivir, and from the confines of Portugal to those of Aragon and Valencia. In 1233 he triumphed over Aben Hud, king of Murcia, Granada, Cordova, Merida, and Seville; and from that year to 1248 he successively obtained possession of Toledo, Cordova, the whole of Murcia, Jaen, and Seville. The loss of the city of Cordova, which in the eyes of the Mahomedans was sacred alike from its magnificent mosque, and from its having been so long the seat of their caliphs, was a severe blow to their power. About the same time King Jayme, the greatest name in the ancient history of Aragon, and surnamed the conqueror on account of his victories, reduced the Balearic Isles, and obtained other important victories. At this period Mahomedan Spain obeyed three sovereigns, who hated each other as cordially as they were all detested by the Christians. Mohammed, who ruled in Jaen, was the least powerful, but the most successful, of these petty kings. He successively got rid of his two contemporaries, and fixed his court in Granada, resolving if possible to extend, or at the worst to preserve, his new states against the independent walis or local governors on the one hand, and the Christians on the other. Thus the celebrated kingdom of Granada was founded in the year 1238, for that of Cordova no longer existed. During two centuries and a half, this Mahomedan state withstood the hostile attacks of its Christian neighbours, and only fell when all Spain became united under one sceptre, and was consequently rendered irresistibly superior to the kingdom of the Moors.

The first king of Granada was equally valiant in war and wise in council, but he was not in a condition to contend with Ferdinand of Castille. He submitted to do homage to him as his vassal; and during the lifetime of Ferdinand a good understanding subsisted between him and Mohammed. But in succeeding reigns war again broke out between the Moors and Christians. In 1303 the strong fort of Gibraltar was reduced by Ferdinand IV. king of Castille and Leon. But the reign of this prince was mostly one of disaster. An iniquitous league was formed by two native princes, who proposed to share the kingdom be-

History.

History. tween them. The kings of France, Portugal, and Granada, were not ashamed to sanction this unhallowed compact. The king of Portugal invaded Castille, the king of Granada spread his ravages into Andalusia, and the fate of Ferdinand seemed on the point of being sealed, and his kingdom partitioned among the combined robbers. But dissensions among the confederates, and the want of money, dissolved the league, and saved Spain. The greatest battle which had been fought between the Moors and Christians since the mighty African host was destroyed on the plains of Tolosa, took place in October 1340, on the banks of the small river Salado. The Christians under Alfonso of Castille were a very small band compared with the enormous host led by the king of Granada; but the former gained a brilliant victory, the loss of the Moors having been immense. The consequence was the surrender of several fortresses; and in the following year the destruction of the Mahomedan fleet was effected by the Christians.

It is now necessary to mention some circumstances in the history of Navarre, relative to the intimate connection which so long subsisted between that kingdom and France, and which had a material influence on the destinies of Spain. The male line of the house of Sancho Inigo, founder of the sovereignty, having ended in Sancho VI., who died in 1234, leaving no issue, the Navarrese elected as their future king, Thibault, a French prince, and nephew to the deceased Sancho. Of this monarch we know little beyond an expedition to Palestine, which he undertook along with several princes of France. His two sons, who successively occupied the throne of Navarre, espoused French princesses, and thus an intimate connection with France was established. The relationship between the two kingdoms became still more close when Queen Jeanne gave her hand to Philip the Fair of France. In short, Navarre became a province of France, and for four reigns has no distinct history. In 1328, however, the kingdoms were again separated, though the sovereigns of Navarre were closely related to those of France. Charles II. surnamed the Wicked, ascended the Navarrese throne in 1349, and shortly afterwards married Jeanne, daughter of King John of France. His reign is one of perfidy, intrigue, and dishonourable alliances. Events which belong more immediately to the history of France, led to the arrest of Charles by the French monarch, and his detention in prison for several years. He effected his escape, and again resumed his old practice of intriguing, particularly against the king of France. In 1366 he entered into a league with the celebrated Black Prince of England, for the restoration of Pedro, surnamed the Cruel, who had been driven from the throne of Castille on account of his many enormities. The expulsion of this detestable monster was the act of an indignant nation, which immediately elevated his bastard brother Enrique, or Henry, count of Trastamara, to the throne of Castille. The exiled king himself appealed in person to the generosity of the English hero, and the consequence was that the Black Prince led a powerful force across the Pyrenees. In his combined army of English and Normans were some of the flower of English chivalry. Henry made every disposition in his power, resolving to hazard all in a battle. The recollection of the cruelties and oppressions of Pedro's government were a strong stimulus to his followers, and might have insured success had he only been opposed by Pedro the Cruel and Charles the Wicked; but he had to contend with the victor of Cressy and Poitiers. The battle which decided the fate of the two kings was fought near Logroño, a few miles south of the Ebro, on the 3d of April 1367. Henry nobly contested the day, as also did his antagonist, who was as brave as he was cruel. The conflict was for a short time desperate, but it terminated in the complete discomfiture of Henry, an event followed by the immediate restoration

of Pedro to the Castilian throne. His gallant ally had soon reason to regret his connection with a prince equally perfidious, debauched, and bloody. Edward quitted him in disgust, without receiving payment of the sum promised to the English troops. Pedro, no longer overawed by the Black Prince, who was as humane as he was valiant, immediately set about punishing those whom he either knew or suspected of having been zealous in the cause of Henry. His late disgrace had sharpened his naturally keen appetite for blood; but we pass over the revolting details of the enormities which he committed. They produced their usual effects, the complete alienation of the minds of his subjects from him, and then a conspiracy to put an end to such barbarous tyranny. Henry, who had fled to France, entered Spain with a small force, which, however, soon became augmented to an army. Tyrants have few friends in the hour of adversity, and those who have been bribed by gold or overawed by authority to become their pliant tools, are too easily seduced from their allegiance to be trusted when the day of trial comes. Mohammed V., king of Granada, was induced to take the field in behalf of Pedro; but it was less to aid his ally than to take advantage of the confusion of the times. Pedro's army gradually melted away, and he himself, compelled to flee for shelter to a fortress, and nearly deserted by his followers, was there shortly afterwards slain by the hand of Henry. Although, as we have already noticed, this prince was a bastard, yet he quietly ascended the Castilian throne, which he bequeathed to his posterity.

For nearly a century after these events took place, the history of Spain presents little or nothing that is remarkable. The continued and petty hostilities between the native princes, or between any or all of them and the Moors, merit but slight attention. Henry IV. surnamed the Impotent, ascended the throne of Castille in 1454. The misconduct of this prince, a frivolous and contemptible debauchee, produced a conspiracy amongst his turbulent nobles, to resist his weak and flagitious administration. He was formally deposed at Avila, in a very extraordinary manner; an effigy which represented him being solemnly degraded from the royal dignities, while at the same time his brother Alfonso was proclaimed king of Castille and León. Henry was naturally anxious to punish the rebels, but they assumed an attitude too formidable for him. Civil war produced a total relaxation of the laws, and let loose bands of robbers, who pillaged the open country, and not unfrequently attacked and plundered the towns. In the midst of these troubles the Infante Alfonso died, an event for the present highly favourable to the king. Some attempts to raise the Infanta Isabella, his sister, to the throne, proved at first abortive; but she was the person upon whom the nobles had set their eyes as the only legitimate successor to Henry. In 1469 was laid the foundation of a union which was to prove of such unbounded advantage to Spain. Juan II. of Aragon solicited the hand of Isabella of Castille for his son and heir Don Ferdinand, king of Sicily. By distributing largesses amongst the Castilian nobles, and firmly attaching the archbishop of Toledo to his interest, Juan succeeded in his object. On the 25th of October 1469, the royal pair received the nuptial benediction in the cathedral of Valladolid. The negotiations had been secretly conducted, and the whole affair was brought to a conclusion without the knowledge of Henry or his queen, a princess as licentious as himself. She had borne a daughter, the Infanta Juana, whom the whole kingdom supposed, on pretty good grounds, to be the fruit of her intrigue with Don Beltran de la Cueva, count of Ledesma, one of Henry's favourites. No sooner was Henry made acquainted with this precipitate marriage, than he resolved to leave no measure untried for securing the crown to Juana. He caused her to be proclaimed heiress of his dominions, and in his last will declared her his suc-

History.

History.

cessor. But popular opinion is too strong even for princes. The country believed her illegitimate, and on the death of Henry in 1474, Ferdinand V. and Isabella were elevated to the throne of Castille and Leon, it being stipulated that the king and queen should reign conjointly. The king of Portugal at first espoused the cause of Juana; but the alliance was productive of no event of importance, and peace was restored between Castille and Portugal in 1479. The very same year, Ferdinand, by the death of his father, Juan II., was called to the throne of Aragon. Having received the homage of his Aragonese subjects at Saragossa, of the Catalonians at Barcelona, and of the Valencians in the capital of that province, he returned into Castille.

The reign of Ferdinand and Isabella is distinguished by great events, events of the highest importance, not only to Spain, but to mankind. It was under their auspices that Columbus brought a new world to light, and it was by their arms that the power of the Mahomedans was for ever extinguished in the Peninsula. Their first object was the regulation of the government and the enforcement of the laws, which, from the license of preceding reigns, had fallen into desuetude, or were openly defied. The king and queen were noted for a rigid administration of justice; neither for money nor favour would they spare the guilty; and there was too much to punish and correct not to give their administration a character of severity, which would have had no existence had the country not fallen into a state of civil and political disorganization almost unprecedented. The local judges were overawed by the nobles, and extraordinary judges or corregidores were appointed to see that they did their duty. This not being found sufficient to eradicate an evil which had existed for centuries, the aid of the Holy Brotherhood was sought and obtained. This association, which had existed since the middle of the thirteenth century, consisted of a number of confederated cities and towns, which maintained a considerable body of troops, in order to protect travellers and pursue criminals, and took cognizance of all violent offences against the laws, appointing courts and judges in various parts of the kingdom. New powers were reposed in this association, so that it became a powerful instrument in the hands of government, and alike terrible to robber and rebel. By this means the territorial jurisdiction of the seignoral nobles was materially abridged, while the royal prerogative was greatly extended. The prompt and impartial administration of justice restored tranquillity and order; and it had been well for the fame of these sovereigns if their salutary severity had been only directed against the disturbers of the public peace. But unfortunately they were equally severe against all who ventured to differ from the established faith. Against apostates, all converts who, after baptism, reverted to Judaism or the faith of Islam, their hatred was implacable. Their intemperate zeal led them to establish, or rather to re-organize, an ecclesiastical tribunal, which became proverbial throughout the civilized world for its enormous cruelties and injustice. This was the court of inquisition.

We now approach what is not only an important event in the reign of Ferdinand and Isabella, but an era in the history of Europe, namely, the conquest of Granada, the last possession of the Mahomedans in Spain. A sovereign so zealous for the Catholic faith as Ferdinand proved himself to be, was not likely to allow such enemies of Christianity to remain long in the Peninsula, if by force of arms he could expel them; and accordingly he early turned his attention to the subject. Every thing conspired to favour his design; the Moorish kingdom was distracted and disunited by a civil war between father and son; and Ferdinand having obtained the bull of Sixtus IV. authorizing a crusade, put himself at the head of his troops, and entered Granada. He continued the war with rapid success; Isabella attended him in several expeditions; and they were

both in considerable danger at the siege of Malaga, an important city, which was defended with great courage, and taken in 1487. Baza was reduced in 1489, after the loss of 20,000 men. Gaudix and Almeria were delivered up to them by the Moorish king Alzagel, who had first dethroned his brother Alboacen, and afterwards been chased from his capital by his nephew Abdali. That prince engaged in the service of Ferdinand and Isabella, who, after reducing every other place of eminence, undertook the siege of Granada. Abdali made a gallant defence; but all communication with the country being cut off, and all hopes of relief at an end, he capitulated, after a siege of eight months, on condition that he should enjoy the revenue of certain places in the fertile mountains of Alpuxarras; that the inhabitants should retain the undisturbed possession of their houses, goods, and inheritances; the use of their laws, and the free exercise of their religion. Thus ended the empire of the Arabs in Spain, after it had continued about eight hundred years.

Its overthrow was soon followed by the expulsion of the Saracens from Spain. This expulsion, however, was not entirely effected till the 17th century. Vast numbers of the Moors, indeed, oppressed by their conquerors, abandoned a country where they could not reside with comfort and with freedom. From the reign of Ferdinand of Castille, to that of Philip III. of Spain, more than 3,000,000 of these people quitted Spain, and carried with them, not only a great part of their acquired wealth, but that industry and love of labour which are the foundation of national prosperity.

The conquest of Granada was followed by the expulsion of the Jews, under circumstances of great injustice and atrocity. This unhappy people had engrossed the greater part of the wealth and commerce of Spain, yet not being allowed to take away the value of their property in the precious metals, they were compelled to barter it for the produce or manufactures of the Peninsula, and this could not be effected except at a great sacrifice. One alternative was left them, to embrace Christianity. The inquisition exhausted first its art and then its fury to accomplish this object, but with comparatively little success. Many, indeed, to save their property, always dear to an Israelite, outwardly at least embraced the faith of the cross; but by far the greater number, in profound despair, and stripped of much of their wealth, took leave of the land of their birth. About the same time that this decree was promulgated, their Catholic majesties concluded an alliance with the emperor Maximilian, and a treaty of marriage for their daughter Juana with his son Philip, archduke of Austria, and sovereign of the Netherlands. To this period also belongs the contract concluded with Columbus for the discovery of new countries; an event which more powerfully than any other attracts the notice of posterity to this splendid reign, and which materially tended to raise the Spanish monarchy above any other in Europe. To Isabella must be ascribed the glory of the enterprise, for she it was who borrowed the sum of money necessary for the armament, and bade the great navigator depart. This great queen died in 1504, leaving her daughter Juana, and after that princess her own grandson (the celebrated Charles V.), heirs to the monarchy, but appointing her husband Ferdinand regent of the kingdom till the majority of Charles. The latter years of Ferdinand's life were embittered by family dissensions, which broke out even before Isabella had breathed her last. Juana was undoubtedly queen, for the Salic law, which excludes females, never existed in Spain. This was well known, and is important, as bearing on events which happened in more recent times. Philip therefore prepared to enforce his right, while Ferdinand, fond of power, and backed by the will of his late wife, showed a determination to maintain his position in the kingdom. But just as the affairs of Spain were assuming a serious aspect, Philip died,

History.

History. and Ferdinand gradually resumed his authority over the whole country. Insurrection quailed before him, the laws resumed their empire, and prosperity revisited the people. The remaining events of his reign must be briefly summed up. He solicited and obtained the hand of Germaine, niece to Charles of France, in the hope of leaving a male heir to the throne; but his anticipations were not realized. In several expeditions to Africa, important conquests were made in that country, Algiers, Tunis, and other places submitting to become vassals to the king of Spain. In 1511 he went to Italy to assist the pope against the schismatics under the protection of the king of France and the emperor. But into the interminable affairs of Italy, the critical wars carried on by Ferdinand in that country in defence of his Sicilian and Neapolitan possessions, we cannot enter. This war, however, led to one memorable result, and one not very glorious to Ferdinand. Desirous of carrying hostilities into France, he demanded from Jean d'Albret, king of Navarre, permission to march his troops through that country. The Navarrese refused, but at the same time promised to remain neutral. He broke his engagement, however, and entered into an alliance, offensive and defensive, with France. Determined to accomplish his end by force, and to punish the duplicity of the Navarrese, Ferdinand invaded Navarre, and in a short time obtained possession of the whole kingdom, annexing it to that over which he formerly ruled, and successfully defending it against the invasion of the French. This was the last great event of Ferdinand's life, and, however fortunate for the country, it was by no means honourable to the king. After a lingering illness, his death took place on the 23d of January 1516. In his last will he declared his daughter Juana heiress to all his dominions in Spain and Italy, and after her his grandson Charles. Cardinal Ximenes Cisneros was at the same time appointed sole regent of Castille till the arrival of his grandson. Ferdinand is justly regarded as the founder of the Spanish monarchy; and although his character has some dark stains upon it, intolerant bigotry being not the least conspicuous, he was certainly the greatest prince of his age, and one of the ablest and best that ever swayed the sceptre of Spain. We shall now glance at the civil and political condition of Spain under the Moors and under the Christians respectively, from the period of the Mahommedan conquest till the death of Ferdinand.

Mahommedan Spain. Mahommedan Spain originally comprehended nearly nine tenths of the Peninsula. Murcia, which the Arabs call Tadmir, though governed by the Christian Theodomir and his successor Athanagild, was as much dependent on the Saracens as Andalusia or New Castille. The districts over which the barbarian sway never extended were the mountains of the Asturias, Biscay, Navarre, and an angle of Aragon. Thus not only by far the greatest, but infinitely the most valuable, part of the Peninsula was comprised in the Mahommedan kingdom. Under the viceroys of the caliphs, and the immediate successors of the first Abderahman, that is, during the first three centuries, it was the admiration and terror of Europe. The revenues which the kings of Cordova derived from their ample possessions were doubtless immense, and this enabled them to maintain not only a large army of native troops, but great bodies of foreign auxiliaries. These mercenary soldiers are supposed by some of the most distinguished Arabian historians to have been the principal cause of the downfall of that splendid monarchy. The spirit of nationality was not destroyed; it was fostered by transplantation from the original soil; the Egyptians in Beja and Lisbon; the Persians in Huete; the Assyrians in Granada; the Berbers and Slavones in most of the great cities, especially about the court; the inhabitants of Damascus, Emessa, and of Old Palestine, in Cordova, Seville, Niebla, Medina Sidonia, and Algeziras; became so many rival factions, all eager in

the pursuit of power, and all mutually hostile. Their frequent quarrels occasioned great disasters in the state, and allowed the ambitious no less than the desperate a long-continued impunity. In this distracted state of the kingdom, rebel chiefs contrived to retain and even to extend their governments; while the Christians, ever ready to take advantage of circumstances, drove the Saracens from city to city, and from province to province, till they finally expelled them from the country. After Cordova fell from its proud eminence, the Mahommedan power declined with great rapidity. The rulers of Toledo, Badajos, Beja, Seville, Ecija, Malaga, Granada, Almeria, Lorca, Murcia, Denia, Valencia, Lerida, Saragossa, and Huesca, all openly aspired to independent sovereignty. Many of these petty states were annihilated by the king of Seville; but his own, with those which still remained, were swept from the Peninsula by Yusef, the first emperor of the Almoravides. This African dynasty was again subverted by the still more ferocious Almohades. In the decline of the latter, the local governors again endeavoured to establish independent kingdoms. The Moorish domination thus became circumscribed within the mountainous region bounded by the sea, and by a line drawn from Malaga through Archidona, Loxa, Guardia, the Sierra de Cazorla, to the environs of Lorca. This small state was still farther limited by the succeeding sovereigns of Castile, from Alfonso el Sabio downwards, till, as we have seen, it was finally subjugated by Ferdinand the Catholic.

In all the states of Spain, whether Mahommedan or Christian, the government was absolute, but not despotic. If the Christian, as a protection against arbitrary power, could appeal to the legal code of the country which he inhabited, the Mahommedan could also invoke the provisions of the Koran, for the laws of the followers of the prophet are founded in their religion. Several of the Mahommedan potentates were the munificent patrons of literature and literary men, the names of some of whom are mentioned with respect at the present day. At the close of the eleventh century, Mahommedan Spain could boast of seventy public libraries, and of colleges, or seminaries of learning, in all the principal cities. Thus learning was much encouraged; and among these numerous collections of books were many hundred volumes by native writers. So great, in fact, was the literary reputation of the Spanish Arabs, that when the caliph of Egypt desired his library to be arranged and indexes to be made, he confided the task to two individuals of that nation. These men of learning comprised historians, poets, grammarians, orators, rhetoricians, mathematicians, astronomers, philosophers natural and moral, physicians, lawyers, and divines. It was in the physical and experimental sciences that the people most excelled, and that too at a time when many of the sciences were wholly neglected or totally unknown in the rest of Europe. Their knowledge of botany was far famed; that of chemistry was still more so. Indeed they are to be regarded, if not the founders, at least the regenerators, of that science in Europe. Their skill in medicine was great; in the mathematics they particularly distinguished themselves; the improvements which they made in algebra are well known. Optics and astronomy were much cultivated by them; nor were the useful arts less attended to, more especially agriculture, including horticulture and planting. The mechanical arts and manufactures were also carried to considerable perfection by the Spanish Arabs. Commerce was deemed no less worthy of encouragement than domestic industry. The fine arts however were less cultivated; but still all the great cities of Mahommedan Spain, Cordova, Granada, Toledo, Valencia, Ubeda, Coimbra, were deeply indebted to the Moorish inhabitants; a fact sufficiently proved by the remains of their past magnificence, which still exist.

History.
Christian
Spain.

From the foundation of the Christian states, the extent of territory comprised by each was usually variable, dependent alike on their conquests over the common enemy and among themselves. The relative extent of each at different periods may be briefly noticed. 1. When Pelayo established his little court at Cangus, the *Asturian* kingdom could only have occupied the mountainous district immediately surrounding that humble capital. By Alfonso I. this territory was extended into Galicia on the west, probably to Aragon on the east, and to the confines of Toledo on the south. Alfonso III. still further amplified the Asturian kingdom, by extending its frontiers to the Sierra de Cuenca, in the territory of Toledo, to the Duero, in Estremadura and Portugal; in one instance even as far as the Guadiana. The capital regularly continued to shift towards the centre of Spain as new territory was acquired. Thus the Asturian kingdom went on increasing till, on the incorporation of Castille with it, and the subsequent conquest of Andalusia by San Fernando, the capital of the monarchy was fixed at Seville. From the reign of San Fernando may be dated the true era of Spanish greatness. Murcia was conquered by his son Alfonso; and by his successors the Moorish kingdom of Granada was first circumscribed and finally subjugated. 2. *Navarre* (that is, Spanish Navarre), from its origin to its conquest by Ferdinand V. underwent little change in its dimensions; and its capital was always Pamplona. See the article NAVARRE. 3. The *Lordship of Barcelona*, which for some time continued dependent on the Carolingian princes, comprehended anciently, not only Catalonia, but likewise Languedoc. The Spanish frontier, however, was subsequently held as a separate government, to which other lordships were subordinate. The dependence on France was of short duration, and appears nearly to have ceased towards the close of the ninth century, when Wifredo II., count of Barcelona, entirely cleared Catalonia from the infidels. That ruler decrees in the sovereign style, and is recognised even by the French as the founder of an hereditary state; which continued as independent a sovereignty as any in the Peninsula, till its union with Aragon, about the middle of the twelfth century. 4. *Aragon* was at first but a small mountainous region at the foot of the Pyrenees, the capital of which was Jaen, or San Juan de la Peña. The conquest of Sobrarbe, Ribagorza, and Pallas, by Ramiro I.; of the Mahomedan fortresses from the Pyrenees to the Ebro by Sancho I.; of Huesca by Pedro; of Tudela, Saragossa, Calatayud, Daroca, Mequinencia, &c. by Alfonso I., amplified this little lordship into a considerable kingdom, the capital of which in 1119 was transferred to Saragossa. When Lerida and Fraga were reduced by the prince of Aragon, the Balearic Isles and Valencia by Don Jayme el Conquistador, Aragon became, next to Castille, the most extensive and powerful of the peninsular kingdoms.

The government of all the Christian states was absolute, and in the whole of them latterly it was hereditary. The powers of the sovereign varied at different times; latterly they became very great. He could concede or revoke, interpret or abrogate laws, declare war or make peace, appoint judges, levy and exact contributions, and the like. But still all was to be done *according to the ancient form*, that is, according to established custom. Other restraints were placed upon his power, and it is pretty certain that the Spanish kings were not commonly tyrannical. The true tyrants were the feudal lords, who were at perfect liberty to exercise almost royal authority within their respective jurisdictions. Of their violence and rapacity there are innumerable complaints in the national chronicles, and in the acts of the Cortes. It is worthy of remark, that the queens presided with their husbands in the Cortes, the councils, and the tribunals of justice, and that as judges, not merely as spectators. The only great feudatories of the crown, exercising a local

jurisdiction, were the condes, who held different ranks and enjoyed different degrees of power. But, from the thirteenth century, the governors of provinces were termed *adelantados* (now captains-general), while those of cities, towns, and fortresses, were known as *alcaldes*. As conquest gave the Christians additional territory, admirals and constables were appointed, with power over the affairs of sea and land respectively. Of the dignities, whatever their names might be, most were doubtless of a mixed nature, partly civil and partly military. But there were functionaries who exercised an exclusively military authority. Among the officers of administration, those of the law must have occupied a prominent place. The judgment in civil or criminal cases properly depended on the counts or viscounts, who sometimes decided themselves, sometimes in concert with men learned in the law, called counsellors, and at other times they left the duty to the ordinary judges. These counsellors or judges were expressly educated for the office, and otherwise well adapted for such a situation. The forms of proceeding, which were simple and brief, were conducted in public, and the sentence was also openly delivered. From the decision of all the ordinary judges, lay an appeal to the royal tribunal, which also took cognizance of certain offences and cases. Spain can boast of an ample body of laws promulgated during the middle ages.

As the circumstances of the country altered, and the state of society advanced, it became necessary to extend or limit the existing laws, and to enact new ones. To encourage the cultivation of waste lands, the Christian kings promised to the lower orders, that if they reclaimed unoccupied wastes, formed themselves into small communities, building villages and towns, and defended their possessions against the common enemy, they should enjoy certain social privileges in addition to the profits of their industry. Of these privileges the most highly prized were those which rescued the people from the jurisdiction of their feudal tyrants, which empowered them to elect their own magistrates, to form municipal juntas, and to dispose of certain revenues arising from forests and other possessions. It may well be believed that so brilliant a reward attracted many settlers, who were thus at once raised from the rank of serfs to that of citizens. Such was the origin of many *fueros*, or provincial laws, which varied in their spirit according to the liberality of the monarch and the relative importance of the colonies. These *fueros* were devised with jealous care to preserve the inhabitants from feudal domination. No baron or noble could settle in a community, unless he abandoned his birthright, enrolled himself among the citizens, and owned obedience to the local *fuego*. So many temptations did these new communities present, in the shape of municipal posts, that many nobles were known to renounce their rank, and class themselves among the plebeians, for the purpose of obtaining them. The defects of such a system were not long in being felt, and a remedy was provided by the introduction of the "*Siete Partidas*," so called from the seven parts into which it is divided. It is by far the most comprehensive code of Spain, being taken from the code of Justinian, the Visigothic, the *Fuero Viejo*, the local *fueros*, as well as from the canon law.

Passing over the much-disputed question regarding the Cortes, origin of popular representation in Spain, we find that there were present, at the Cortes held at Leon in the year 1188, "the deputies of towns, chosen by lot," that is, representatives of the people, the third estate. On these municipal towns many important privileges were conferred by successive sovereigns, the direct tendency of which was to abridge the powers of the feudal lords. But even at the brightest period of popular representation, which was the fourteenth century, the representation was never definite. Many of the great towns neglected to send any deputies at all, and those which

History.

History. did return them appear to have observed little proportion in the numbers. Two was the number which ought to have been returned by each, but some towns sent eight, while others of larger size sent only one or two. Indeed it seems highly probable that the privilege of sending deputies was a favour granted by the sovereign to such towns as it was his pleasure to honour. It is preposterous, therefore, to look upon the third estate as consisting of independent representatives of the nation: the members were little better than nominees of royalty, and their numbers could be increased or diminished just as it suited the purposes of government. Much as the popular representation of Castille is extolled by national writers, it seems to have been better adapted for securing and extending the power of the crown, than for protecting the rights of the people. Under Ferdinand and Isabella the last lingering traces of popular liberty were destroyed; but the power of the other orders of the state suffered at the same time a corresponding diminution, as we have already noticed. Such is a brief outline of the government and laws of Castille and Leon, the most important of the peninsular kingdoms, and almost the only ones in which the reader will take much interest, or, indeed, regarding which authentic documents remain. It may be mentioned, however, with regard to the kingdom of Aragon, that, with the exception of the lowest order, the serfs of the soil, the Aragonese possessed a greater share of individual liberty than any other people in the Peninsula. The citizens and nobles frequently coalesced for the purpose of obtaining fueros or privileges from the crown, and when thus united they were generally too powerful to be resisted. Hence numerous concessions were made by successive sovereigns, and an amount of popular freedom obtained by the people which frequently threatened the existence of the monarchy itself. Catalonia and Valencia were always distinct from Aragon, both in government and laws. Each had its Cortes, consisting of three estates, prelates, nobles, and deputies, all no less tenacious of their privileges than those of Aragon.

Literature, science, and religion. Several historians of note, whose works have come down to us, flourished in the various Christian kingdoms of Spain during the period of Mahomedan domination. Poetry sprung up about the middle of the twelfth century, and some very interesting specimens of these ancient compositions still remain, particularly the *Poema del Cid*. The old Spanish ballads are well known, and celebrated throughout Europe. The scientific state of Spain, as compared with the Mahomedan, exhibits a lamentable contrast; nor does it appear that in any of the useful arts of life the Spanish Christians were equal to the Moors. The most distinguished place in Spanish science during this period has been assigned to Alfonso X. surnamed el Sabio; but even he was greatly indebted to the Arabians for the perfection which he attained. The theologians of Spain, during the middle ages, were more numerous than all her other writers put together, and the writings of many of these shining lights of the church are to be met with in the libraries of Spain. With regard to religion it is only necessary to state, that the Catholic faith prevailed in full force, and was characterized by the darkest bigotry and the fiercest intolerance, as the doings of the inquisition amply testify.

Charles I. Charles I. (V. of Germany) became king of Spain on the death of Ferdinand, but a regency had been nominated to govern the kingdom until he should attain his twentieth year. If the events and transactions in which this monarch was concerned were to be woven into the history of Spain, it would in fact be the history of almost all Europe during the period of his reign. But our business is with events purely peninsular; or if others of a more general character are occasionally noticed, it will be because they are too closely connected with the former to be separated without violence. His foreign wars, negotiations, and other trans-

History. actions, arose from his position as emperor of Germany, not from his being king of Spain; and an account of them will be found under the heads FRANCE, ITALY, and ENGLAND, to which articles the reader is referred.

The Cardinal Ximenes Cisneros, to whom the regency had been left by the deceased king, was bitterly opposed in his administration, principally by the nobles of Castille, who, envious of his dignity, displeased with his firmness and vigour, and hoping for impunity under a young monarch, soon showed a disposition to refuse him obedience. Popular discontent reached a great height; and as his best measures were misrepresented to the king, Charles perceived the necessity of making his appearance in Spain, where he arrived in 1517. Nobles and prelates hastened to meet their sovereign, and among the rest the calumniated Ximenes. But that sovereign he was not destined to see; he suddenly sickened and died, not without suspicions of poison. Charles brought with him a multitude of Flemings from the Netherlands, who soon monopolized the principal situations in church and state, and in all their dealings evinced an unquenchable thirst for gold. The favour extended to these foreigners so incensed the people, that Charles found extreme difficulty in obtaining the homage of the Spaniards. Although they swore allegiance to him, it was on certain stipulated conditions, sufficiently advantageous to themselves. In 1519 occurred an event destined to exercise great influence over his future life, over his hereditary states, in fact over all Europe. This was his election to the imperial throne of Germany, left vacant by the death of his paternal grandfather Maximilian. The Spaniards were pleased that this dignity was conferred on their sovereign; but as the old grievances continued to gall them, they were not so dazzled as to be insensible to their own interests. The leading men of many of the principal cities publicly remonstrated with Charles, and it was only by granting certain concessions that he could keep them from open rebellion. His presence having become absolutely necessary in Germany, he quitted Spain, but proceeded first to England to concert with Henry VIII. the means of humbling the power of the French king, Francis I. This monarch had been a candidate for the imperial diadem; but, disappointed in his ambition, and in hatred of his successful rival, he leagued himself even with the enemy of the Christian faith. He also laid claim to Italy, the Netherlands, and Navarre; so that war was unavoidable, and hostilities immediately commenced; for an account of which see the articles already referred to.

The turbulence of the times was not likely to be assuaged by the absence of the king from his all but revolted territories in the Peninsula. Opposition had now degenerated into rebellion; and what before might have been dignified with the name of patriotism, could only be characterized as crafty schemes of personal ambition. Unfortunately for the interests of order, the regency of Castille, where disaffection had assumed the most serious aspect, was held by a man, estimable and virtuous, indeed, but little fitted for such stormy times. The appointment of this individual, Cardinal Adrian, who subsequently wore the triple crown, had at the first given great offence to the nobles and deputies at court; but the king, though solicited, would not change him for another. The persons upon whom the fury of the mob fell were chiefly the governors and deputies of the cities and provinces. Many were massacred; open insurrection spread from city to city; and no species of crime was left uncommitted. In this critical position of the royal cause, it was fortunate that Aragon, Catalonia, and most of Andalusia, stood aloof from the confederation. Had they joined it, the evils might have been long protracted, and the whole Peninsula plunged in misery and ruin. But the revolted cities followed one another in making their submission to government; and those which did not voluntarily

History. submit were reduced by the royal troops, now augmented to a considerable body. An attempt of the French king to seize Navarre was happily frustrated, so that in 1522 the whole country was restored to tranquillity.

In July of that year, the emperor, whose presence had been often requested by the royalists, arrived in Spain. It was expected that summary justice would be inflicted on those who had taken a prominent part in the recent disturbances; but on this occasion Charles showed a degree of clemency almost unexampled in history, very few being condemned to suffer. During the remainder of this prince's reign, the domestic tranquillity of Spain was undisturbed, except by an insurrection of the Moors, which was soon suppressed. Of two expeditions of the emperor to the African coast, to humble, if not to extirpate, the Mahomedan pirates, one was successful, the other disastrous. He compelled the Grand Turk, who penetrated into the centre of Europe, to retreat; and took his great rival, Francis I. of France, prisoner at Pavia. Such were some of his achievements in his foreign wars, by which the fame of the Spanish arms was extended throughout Europe. The mines of the west also had begun to pour their inexhaustible wealth into the country, so that the military and political power of Spain now attained its zenith, and became a source of uneasiness to other nations. In 1525 Charles married the Princess Isabella, sister of Joam III. king of Portugal. The issue of this union was, besides two daughters, the infant Philip, destined to be no less famous than his father. Charles made an ineffectual effort to procure for him the imperial crown of Germany; but in 1554 succeeded in obtaining the hand of the princess Mary of England. That the nuptial ceremony might be performed with greater splendour, he invested his son with the regal title, by abdicating in his favour his Italian possessions, the kingdoms of Naples and Sicily, and the duchy of Milan. This was but a prelude to a still more extraordinary sacrifice. It appears that from the very prime of life the emperor had meditated a retreat from the world; and that on the death of his mother Juana, in 1555, he was determined on fulfilling his long-cherished project. Many reasons have been assigned for this memorable act, but the principal cause is to be traced to his superstitious temperament; something is also to be allowed for the bad success of his arms during the latter years of his reign. Having concluded a truce with Henry, the successor of Francis, and recalled Philip from England, he assembled at Brussels the states of the Netherlands. There, amidst the most imposing solemnity ever witnessed since the days of the Roman Cæsars, he resigned the sovereignty of the Low Countries into the hands of his son. With the same august ceremony he resigned the crown of Spain, and the dominions thereto belonging; and from the monastic retreat to which he retired, he sent his resignation of the imperial diadem. The place which he had chosen for his residence was the monastery of St Justus, one of the most secluded and delightful situations in Estremadura. Here, employed in religious observances, passed the latter years of the life of the most powerful sovereign Europe had seen since the days of Charlemagne and the empire of the west. His character has been variously described by natives and foreigners; the former can see little in it to condemn, the latter nothing to admire. His policy was always close, sometimes crooked, and in not a few instances dishonourable. He was no friend either to civil or religious liberty, and may safely be pronounced a bigot. Under him the condition of Spain was more splendid, perhaps also more prosperous, than in any prior or subsequent reign. Notwithstanding his many wars, the people do not appear to have been overburdened in supporting them, for the New World poured its treasures at his feet. A new impulse was given to national industry by the markets opened for Spanish productions in the transatlantic colonies. But the brightest landscape has its masses of shade. The

nobles held a power over the people which was often exercised with violence. Favouritism to foreigners was practised to an unprincipled extent, and the sale of offices became a branch of traffic. Another baneful evil was the multiplication of religious orders. Lastly, the exemption from taxation of the nobles and clergy, which threw the whole weight of public contribution on the third estate, increased the disaffection of that body, and was one of the chief causes of the subsequent decline of the kingdom. For an account of the private life and character of Charles, see the article CHARLES V.

The reign of Philip II. commenced in 1556, and extended to the year 1598. Much of it was occupied in foreign wars, to which we can only briefly advert. For an account of Philip's long, bloody, and inglorious struggle with his revolted subjects of the Low Countries, see the article HOLLAND. The circumstances which led to the invasion of Portugal, and the annexation of that kingdom to the Spanish crown, will be found fully detailed under the head Portugal. An attempt was made by the pope, in conjunction with France, to wrest from Philip his Italian dominions, but without success. The duke of Alva, the viceroy of Naples, put his troops in motion, seized several fortresses of the papal states, and the holy city began to tremble for its security. Philip himself invaded France, and inflicted a severe blow on Henry under the walls of St Quentin. The French army, under the duke of Guise, was recalled from Italy; and the pope, left at the mercy of the duke of Alva, was compelled to purchase his safety by withdrawing from the French alliance. In 1559 peace was made with France; and Philip having become a widower, further ratified the treaty by marrying Elizabeth, sister of the French king. But the Turks continued to harass Naples, although they durst not make a stand before the Spanish forces. In 1565, Philip assisted the Maltese with 10,000 Spaniards in the famous siege which they underwent from sultan Solymán. Five years afterwards, the war between the Venetian republic and the Porte again brought the Spaniards into collision with the latter power, and they had no small share in achieving the glorious victory of Lepanto. The Mahomedans, however, still continued to make descents on the Italian coast, and to harass the African possessions of Philip; but, on the whole, the war with the misbelievers was honourable to the Spanish arms.

We now approach an event of peculiar and lasting interest to every Briton, the projected invasion of England by the famous Spanish Armada. Elizabeth had certainly done much to provoke the resentment of Philip. She had succoured the insurgents of the Netherlands, fomented the disturbances in Portugal, assisted France, and her naval captains had ravaged the dominions of Spain in both hemispheres. Philip's patience being exhausted, he prepared a mighty armament for the invasion of England. A complete account of this famous attempt to plant a foreign standard on our shores, and its disastrous termination, will be found in the article ENGLAND. A second expedition for the invasion of Ireland shared the fate of the former; and this effectually cured Philip of all ambition to attempt the subjugation of the most hated of his enemies.

The revolt of the Moriscos occupies a remarkable place in the native annals of the sixteenth century. These Christianized Moors still remained Mahomedans at heart, making amends for compulsory apostasy by celebrating in secret the rites of their religion. It was the jealous policy of Spain to destroy, if possible, every vestige of their nationality. To effect this end the government had recourse to severe and unjust measures, which produced open revolt and civil war in Granada. Dreadful atrocities were committed by the Moriscos, and fierce was the retaliation of the Christians. The war raged with various success for some time, but how the struggle must terminate

History.

History. could never for a moment be doubtful. The Moriscos fled to the mountains, the ancient asylum of liberty; and in the deep caverns with which they abound they deemed themselves secure. But thither they were hunted by the Christians, and, like wild beasts, smoked to death by fires kindled at the mouths of these subterranean retreats. All who were in arms were cut off in this manner, or by the sword. The total expulsion of the Moriscos, however, did not take place till a subsequent period. To some affairs of a private or more trivial nature it is unnecessary to advert, although some of them deeply implicate the character of Philip. This prince died in September 1598, in the palace of the Escorial, of which he was the founder, and which is the noblest monument of his reign. By the last of his four wives, Anne of Austria, Philip left a son, who succeeded by the title of Philip III.; his other male children preceded him to the tomb. Don Carlos, one of these, is generally believed to have been murdered by the command of his bloody and unrelenting father. The character of Philip was gloomy, stern, and cruel; he was suspicious, dark, and vindictive, the irreconcilable foe of civil and religious liberty, for which there can only be brought forward as a palliation his zeal for what he called religion. But Philip was eminently prudent, attentive to public affairs, and what he conceived to be the best interests of his country. It has been supposed that the sceptre of Philip was swayed over 100,000,000 of human beings, including the population of all the foreign possessions of Spain. At this time the state of the inhabitants of the Peninsula was one of comparative comfort. Agriculture, manufactures, and commerce, flourished to an extent even greater than in the best period of the emperor's reign. Yet all his vast resources, especially in the New World, were unhappily wasted by Philip; and his own policy destroyed the very foundations on which they rested, and hastened the decay, or rather ruin, of the kingdom. The measures which exercised so fatal an influence over the destinies of Spain may be briefly enumerated. 1. His persecution of the Flemings and Dutch, which led to a revolt that cost him 150,000,000 of ducats; 2. his war with England, no less expensive and disastrous; 3. the treasures sent to support the abominable Catholic league, and wars in other quarters; 4. the subjugation of the Moriscos, and the proceedings of the inquisition, by which the most productive and useful classes of his subjects were ruined or expatriated. From these and from other minor causes, notwithstanding the enormous revenues and resources of the kingdom, Philip died insolvent.

Philip III. The greatness of Spain having passed away with Philip II., from this period it declined with fearful rapidity. For a long period there is little to be recorded beyond the reign of worthless favourites, the profligacy of courts, and the feeble efforts of a government struck with mortal paralysis. Our retrospect of these reigns will therefore be characterized by a brevity corresponding with their importance. The most signal event of Philip III.'s reign was the total expulsion of the Moriscos from all parts of Spain where they had sought a home during the struggle recorded in the last reign. The loss to agriculture and commerce, for they were by far the most ingenious and industrious portion of the community, and the blow which would be inflicted on the national prosperity by the withdrawal of so much wealth as they possessed, were never taken into account by the duke of Lerma, the prime ministers, nor any of his inquisitorial councillors. Orders were issued for their immediate expulsion in September 1609, and no fewer than 600,000 individuals were forcibly dragged from their homes, and landed on the African shore, there to be treated even worse, by the most cruel and perfidious of the human family. The foreign transactions of this reign are unimportant. Philip III. died in March 1621, leaving his kingdom to a son who bore his name, and also inherited his imbecility.

Philip IV. ascended the Spanish throne in his seventeenth year. Profligate extravagance and dissipation soon began to characterize the proceedings of the court, and murmurs and complaints to agitate the people, who were exhausted of their wealth in supporting pantomime and mummery at home, and iniquitous wars abroad. The reins of government were surrendered into the hands of the Conde de Olivares, a worthless favourite. An attempt to enforce an obnoxious measure drove the Catalans to revolt. They sought and obtained the aid of France, and this occasioned a feeble and unimportant war, which languished till 1660, when peace was concluded, but not till Spain had surrendered part of her territory to France. Contemporary with the origin of the Catalan insurrection was that of Portugal, by which the Portuguese freed themselves from the Spanish yoke. See PORTUGAL. During his long reign, Philip was frequently at war with England, Holland, and France, and every power committed fearful ravages on his territories. England took Jamaica during this disastrous and disgraceful period of Spanish history. In Naples, a terrible shock was sustained in 1646, by the insurrection of Massaniello. See the article NAPLES. But the most calamitous of Philip's transactions was the war in the Low Countries, which terminated in his recognising the independence of the seven United Provinces. Philip died in 1665. His character needs no description. Since the days of Roderick the Goth, a more disastrous reign than his had not darkened the annals of Spain.

Charles II. son of Philip IV. succeeded to the throne when only four years of age. As the affairs of the kingdom were then situated, they were not likely to improve under a child; and it was a further misfortune, that throughout his long reign the king remained little better than a child. He was feeble in body, and next to imbecile in mind; in proof of which it may be mentioned, that he believed himself bewitched, and submitted to the exorcisms of his confessor with devout solemnity. Louis of France, who espoused Maria Teresa, sister of Charles II. by a prior marriage, in right of his wife preferred a monstrous claim to the Low Countries, and poured his legions over the frontier to make it good. The union of Sweden, Holland, and England, to oppose the ambition of the Frenchman, saved the whole Netherlands from subjugation; but by the peace of Aix-la-Chapelle Louis retained the most valuable of the conquests which he had made. In this reign the complete independence of Portugal was recognised. In 1672, France invaded Holland, now the ally of Spain, conquered Franche-Comté, which belonged to Spain, made some destructive inroads into Catalonia, and reduced some fortresses in the Low Countries. By the alliance against France, in which England, Germany, and Spain joined, Louis's career of ambition was effectually checked. But subsequently he reduced Valenciennes, Cambray, St Omers, and other places; Ypres and Ghent were assailed with equal success; and a place on the Catalan frontier also yielded to his arms. Most of these places, however, were restored at the peace of Nimeguen in 1678, one of the conditions of which was, that Charles should receive the hand of Maria Louise, niece of the French king. On the death of this princess in 1689, the French again poured the storm of war over the frontier of Catalonia. Destitute of money and of troops, Spain trembled to her most distant extremities. But circumstances of a delicate nature, into which we shall not enter, induced Louis to restore all his conquests at the peace of Ryswick in 1697. The health of Charles, always infirm, now rapidly declined, and he expired on the 1st of November 1700. He was the last of the Austrian dynasty; and glorious as the condition of Spain was under its early sovereigns, those who succeeded them had brought the kingdom to the verge of ruin. From the accession of the third Philip it had declined, from causes already specified.

History.
Philip IV.

Charles II.

History. The condition to which it was now reduced was pitiable. The army and navy were in a state of utter disorganization; the walls of towns and fortresses were in ruins; the public revenues had dwindled to little more than a nobleman's income; and trade, manufactures, and commerce, had all but ceased to exist. Another such reign as that of Charles II. would have dissolved the bonds of society.

Philip V. Charles II. was succeeded by Philip V. duke of Anjou, grandson to Louis XIV. of France. He was the eldest son of Maria Teresa, eldest daughter of Philip IV., consequently the most legitimate sovereign; for Charles left no issue, and before his death he had subscribed an instrument, declaring Philip his successor. The foreign events of this reign demand our first attention. The transactions of the war which was soon declared against France and Spain, by England, Holland, and the empire, assisted by Savoy, Portugal, and Prussia, have been already related under the article **BRITAIN**. The chief objects of the alliance were to obtain satisfaction for the Austrian claims on Spain, the emperor Leopold being not only descended from Fernando, brother of Charles V., but whose mother was the daughter of Philip III.; to rescue the Netherlands from France; to prevent the union of the French and Spanish crowns; and to exclude subjects of the former from the Spanish possessions in the West Indies. The treaty of Utrecht, which terminated the differences between the principal contending powers, was signed in 1713; and in 1715 a permanent peace was concluded between Spain and Portugal. By the celebrated treaty of 1713, Spain was stripped of half her European possessions. Philip was indeed acknowledged king of Spain and the Indies; but Sicily was ceded to the duke of Savoy; Milan, Naples, Sardinia, and the Netherlands, to the emperor; and Gibraltar and Minorca to the English. The Catalans, who had revolted and joined the allies, were likewise guaranteed a general amnesty, but without any stipulations for the preservation of their ancient fueros or privileges, which they had justly forfeited. Philip also renounced, both for himself and his successors, all claims to the French crown. In return for this renunciation, he forced rather than persuaded his council to introduce a measure to which subsequent events in the history of Spain gave great importance. This was to alter the order of succession, and establish a sort of Salic law, by which the most distant male of the family would be called to the inheritance in preference to the nearest female. The innovation was regarded with discontent. By the ancient law, which, in default of direct male issue, called females to the throne, the monarchy had been formed. By it Catalonia had been united with Aragon, and the latter with Castille; and by it Philip himself had inherited the crown.

Philip made an unsuccessful attempt to recover Sicily, Sardinia, and Naples; for he had now rendered both his navy and his army formidable alike by discipline and numbers. His fleet, however, was totally destroyed off the coast of Sicily, by our Admiral Byng, in the year 1718.

By a new treaty in 1720, Sardinia was given to the duke of Savoy, and Sicily to the emperor; and by the treaty of Seville, concluded in 1729, the duchies of Tuscany, Parma, and Placentia, were ceded to Spain. In 1731, the Spanish king invaded Naples, took possession of that kingdom, and conferred it on his son Don Carlos, in consequence of which war was declared between Spain and the empire in 1733. At the end of that year the palace of Madrid was consumed by fire, and all the archives relating to the Indies perished in the flames. In 1739, hostilities were renewed between Spain and Britain; but the only successes obtained by the latter power were the capture of Porto Bello by Admiral Vernon, and that of the Manilla galeon by Commodore Anson. Philip's long and turbulent reign was now drawing to a close. In July 1746, he was hurried to the grave by an attack of apoplexy. One memorable event of his

reign remains to be noticed. In imitation of the emperor, he resigned the cares of royalty into the hands of his son in 1724; but finding seclusion irksome, he resumed them again in a very short time. Whatever might be the weaknesses of this prince, he had a sincere desire for the good of Spain, and retrieved it from hopeless ruin by several judicious measures which he introduced, so that the country attained a degree of positive prosperity unknown since the days of the second Philip.

Ferdinand VI. a mild, prudent, and beneficent prince, reformed abuses in the administration of justice and management of the finances. He revived commerce, established manufactures, and promoted the prosperity of his kingdom.

Charles III. succeeded Ferdinand in 1759. The famous family compact was concluded at Versailles in 1761, among the four kings of the house of Bourbon. The English, alarmed by the naval preparations of Spain, declared war in 1762, and took Havannah in the island of Cuba, and Manilla in the East Indies. Notwithstanding this success, peace was hastily concluded at Fontainebleau, in November, by which the Havannah was restored. In 1767 the Jesuits were expelled from Spain. An unsuccessful expedition was concerted against Algiers in 1775, the particulars of which it is unnecessary to detail. In the war between Great Britain and her American colonies, Spain, by the intrigues of the French court, was instigated to take up arms in support of the latter. At the conclusion of that calamitous war, Great Britain, in a treaty with Spain, ceded to this power East and West Florida, and the island of Minorca. Charles died in 1788, and was succeeded by his second son Charles Anthony, prince of Asturias, the eldest having been declared incapable of inheriting the crown.

Charles IV. had not long been seated on the throne before the portentous revolution in France involved Europe in a general scene of political and military contest. The king of Spain joined the general confederacy against the new republic, and in consequence was numbered among the objects of its resentment, by a declaration of war in 1793. The military operations of Spain, however, were extremely languid; and after two campaigns, in which she might be said to carry on rather a defensive than an offensive war against the republican armies, she was compelled to conclude a treaty of peace, which was signed at Basel on the 22d July 1795. By this treaty the French republic restored to the king of Spain all the conquests which she had made from him since the commencement of hostilities, and received in exchange all right and property in the Spanish part of St Domingo.

This treaty was soon followed by a rupture with Great Britain. On 5th October 1796, the court of Spain having published a manifesto against this country, the court of London made a spirited reply; and about the same time was published a treaty of offensive and defensive alliance, which had been concluded about two months before, between the king of Spain and the French republic. In the war which followed between Spain and Great Britain, his Catholic majesty could boast of but little honour or success; and the French republic gained little from its new ally but the contributions of money which it from time to time compelled him to advance. On the 14th of February 1797, a Spanish fleet of twenty-seven sail of the line was defeated by Sir John Jervis off Cape St Vincent, and four of the Spanish line-of-battle ships were left in the hands of the victors. From this time till the temporary cessation of hostilities by the peace of Amiens in 1802, there is nothing remarkable in the transactions of Spain.

On the renewal of the war in 1803, Spain was again compelled, by the overbearing power of France, to take an active part against Great Britain, and fitted out a formidable fleet, which was united to a considerable naval force belong-

History.

Charles IV. 1788.

Engages in the confederation against France. 1793.

War between Spain and Britain. 1796.

1797.

1803.

History. ing to the French. The Spanish declaration of war against Britain is dated at Madrid on the 12th of December 1804; 1805. and on the 21st of October 1805, the combined fleets of France and Spain were annihilated by Lord Nelson off Cape Trafalgar. After this terrible blow to the naval power of Spain, nothing of importance took place till 1808, when the liberties of Spain were subverted by the machinations of Napoleon. The designs of the French emperor, long suspected, became sufficiently apparent in 1808. Unfortunately the dissensions of the royal family of Spain were so favourable to his plans, that they may be said to have hurried on their execution. The dark and tortuous policy by which he effected his purpose, and the course which events took in Spain, will be found detailed in the article FRANCE, so that only a brief notice of the leading facts will be given in this place. At this time (1807) the management of state affairs was in the hands of Don Manuel Godoy, the favourite of Charles IV. and his queen, and better known by the name of the Prince of Peace. He had been raised from the humblest station to be the richest and most powerful subject in the kingdom, and to fill its highest posts. Ferdinand, the prince of Asturias, had refused to marry the sister-in-law of this fortunate minion, and to secure himself from his vengeance he wrote to Napoleon asking for protection. At the same time he exposed the administration of Godoy, in a letter to his father, and requested to be allowed some participation in the government. This so enraged the queen that she ordered his immediate arrest; but, on asking pardon of the king, Ferdinand was restored to liberty, not however before Charles had taken the fatal step of appealing to Napoleon regarding his son's supposed treasonable conduct. The emperor of France was thus constituted umpire between father and son. French troops poured into Spain, which was thrown into a ferment by the rumour that the royal family were preparing to fly to America. Popular indignation was kindled against the hated favourite, who narrowly escaped with his life. At length Charles abdicated in favour of his son, but two days afterwards privately protested against his own act, and sent a copy of this strange paper to Napoleon, who afterwards made it a pretext for his ulterior designs.

Ferdinand VII. The prince of Asturias, now elevated to the throne under the title of Ferdinand VII. made his triumphal entry into Madrid. Shortly afterwards he was induced to undertake a journey to Bayonne to meet Napoleon, and consult about the affairs of the kingdom. This memorable interview took place, and the eyes of Ferdinand were now thoroughly opened to the designs of the French emperor, by finding himself a captive in his hands, and his right to be considered king of Spain rudely denied. The rest of the royal family eagerly rushed into the snare set for them by the master of toils at Bayonne. Here father and son surrendered the crown of Spain into the hands of Napoleon, by whom it was transferred to the head of his brother Joseph. But such a momentous event as a change of dynasties, effected under circumstances of such atrocious perfidy, could not take place without rousing every loyal and every indignant feeling in the bosoms of the Spanish people. No sooner was the fact of the renunciation known, than the northern provinces burst into open insurrection. Asturias and Galicia set the example; and it was soon followed by almost every part of Spain not immediately occupied or overawed by the armies of France. One of the first steps taken by the leaders of the insurrection was to assemble the juntas or general assemblies of the provinces. When these were organized, they issued proclamations, calling on the Spaniards to rise in defence of their sovereign, and in the assertion of their own independence. Besides these proclamations from the provincial juntas, addresses were published in almost every province by the leaders of the popular cause; in particular, the province of Aragon

History. was addressed by Palafox, a name celebrated in the annals of the Spanish revolution, in a bold and spirited manifesto. The junta of Seville, which assembled on the 27th of May, formed itself into a supreme junta of government, caused Ferdinand to be proclaimed king of Spain, took possession of the military stores, and issued an order for all males from sixteen to forty-five, who had no children, to enroll themselves in the national armies. On the 4th of July the alliance of Great Britain with the Spanish nation was proclaimed, and a struggle began which terminated in the complete expulsion of the French from the Peninsula. The events of this celebrated war will be found recorded in the article BRITAIN.

The loss of the royal family, by which they were deprived of a directing power, a legitimate head to give the constitutional stamp to their proceedings, plunged the Spaniards in great difficulties. Unity of opinion was wanting to the junta, and vacillation and weakness marked its proceedings. It was unfortunate, that while one spirit animated the mass of the people against the French, many of the nobles and other influential individuals had given in their adhesion to the French dynasty. The successes of the latter were attributed, probably not without some reason, to treachery; and more than one Spanish general fell a victim to public indignation, whether justly or unjustly cannot now be known. But whatever victories the French gained, they only remained masters of the places which they occupied. A vast system of guerilla warfare had been organized and vigorously prosecuted, which served to preserve the energy and confidence of the nation unbroken. The guerillas everywhere surrounded and harassed the French; no line of communication was safe for them. These petty achievements, however, could not compensate for the loss of battles on a large scale, and the capture of fortresses, the strongholds of the kingdom. The supreme junta fell under suspicion, and, unable to sustain the weight of government and the storm of public indignation, it was agreed that the Cortes should be convoked, and a regency appointed. The manner in which this celebrated Cortes was constituted has been a subject of keen disputation; but the circumstances in which the kingdom was placed at the time, rendered it impossible for the members being chosen according to the ancient forms. It has been alleged that this assembly was of a much more popular and democratic nature than the regular Cortes, which is undoubtedly the fact. It ought to be recollected, however, that the nobles were a suspected body, and therefore the burgesses and others might consider it dangerous to admit their voice in a matter which involved the liberties of the kingdom. But, we repeat, the situation in which Spain stood at this eventful moment made it a matter of necessity for those who directed the affairs of the nation, to act as they did. Had not the progress of the French armies dispersed the central junta, and concentrated the fugitive patriots at Cadiz, it is more than probable that the Cortes would have been assembled according to the ancient forms, and that the privileged classes, supported by the majority of the nation, would have defeated any attempt to alter the old constitution. But Cadiz offered to that party which has been since known by the name of liberal, the most favourable opportunity of striking a deadly blow at the very root of the monarchical power under which they had so long groaned in hopeless yet silent restlessness. Cadiz was not only in itself a place much more democratic than any other in Spain, but during the usurpation of the French it had become the asylum of all who professed liberal principles. As they generally belonged to that numerous class of the Spanish gentry who look up to the patronage of government for the means of subsistence, the court drew them together from the provinces. On the prospect of the political changes which the captivity of Ferdinand opened to the country, these men attached themselves to the central junta, and finally followed its members in their flight from

History. Seville to Cadiz. Hither, too, flocked all the stragglers of the philosophical party; and on the dissolution of that dull, dilatory knot of ill-assorted men, who, under the veil of dignified gravity, had for a time concealed their unfitness to direct the nation, the Spanish speculatists found themselves in the midst of a population highly disposed to listen to their doctrines, to approve their views, and constitute them the organs of the new laws which were to remodel the kingdom.

New constitution.

The majority of the first Cortes being composed of liberals, the project of a constitution was immediately set on foot, and a committee of the ablest members appointed to draw up the fundamental code of the monarchy. Such a task, at all times arduous, was, in the present circumstances of the country, beset with peculiar difficulties. Encouraged by the absence of the king, placed beyond any check from the privileged classes, and the weight of the landed property of the country, it is not surprising that the framers of the constitution allowed their zeal to carry them too far, especially when it is considered that the Spanish people were almost entirely unaccustomed to the exercise of civil rights. The government was wholly remodelled, so that from being the most absolute monarchy in Europe, it became the most strictly limited of all limited monarchies. As this constitution, with the exception of a few alterations, is nearly the same as that which is now in force, our introducing it in this place will serve to give greater clearness to the subsequent narrative of events. It was drawn up by 184 members of Cortes, on the 18th March 1812. On the 20th of the same month the regency, which consisted of Cardinal Bourbon and two other apparently incapable individuals, took the oath to maintain it. This constitution was acknowledged by the allies of Spain, namely, Great Britain, Sweden, Denmark, Prussia, Russia, and other states.

By one of the first articles in the code, the sovereignty is declared to reside essentially in the nation, which, being free and independent, neither is nor can be the patrimony of any person or family. All Spaniards, without distinction, are subject to taxation. "The religion of the Spanish nation is, and shall be for ever, the Catholic, Apostolic, and Roman, which is the only true religion." "The nation," it is added, "protects it by wise and just laws, and forbids the exercise of any other whatever." The government of the Spanish nation is stated to be "a limited hereditary monarchy." The power of making laws is vested "in the Cortes, jointly with the king." In describing the class of Spaniards who enjoy the privileges of citizenship, persons "reputed of African origin, either by the father or the mother's side," are excluded. A similar exclusion is given to Spaniards who obtain naturalization in another country, or who, without leave, absent themselves five years from Spain. The only basis for the number of representatives in the Cortes is *population*, to be taken from the census of 1797, till one more correct can be made. For every seventy thousand souls there is to be one deputy in the Cortes. The returns of the members are made by three successive elections. Every parish appoints electors for the district to which it belongs. These repair to the chief town of the district to choose another set of electors, who, lastly, meeting in the capital of the province, make the final appointment to the Cortes. The Cortes are triennial. No member can be elected for two successive representations. No debate can be carried on in the presence of the king; his ministers may attend and speak, but are not allowed to vote. There is a permanent deputation, or committee of the Cortes, composed of seven members, appointed by the whole body, before a prorogation or dissolution, whose duty

History. is to watch over the executive, and report any infringement of the constitution to the next Cortes. It also belongs to them to convoke an extraordinary meeting of the Cortes in the cases prescribed by the constitution.¹

The powers of the Cortes are chiefly these: 1st, To move and pass the laws, and to interpret and alter them when necessary; 2d, to administer the constitutional oaths to the king, the prince of Asturias, &c.; 3d, to determine any doubt or fact relative to the succession; 4th, to elect a regency, and define its power; 5th, to make the public recognition of the prince of Asturias; 6th, to appoint guardians to the king while a minor; 7th, to approve or reject treaties previous to ratification; 8th, to allow or refuse the admission of foreign troops into the kingdom; 9th, to decree the creation or suppression of offices in the tribunals established by the constitution, as well as of places of public trust; 10th, to fix, every year, by the king's proposal, the land and sea forces; 11th, to regulate the military code in all its branches; 12th, to fix the expenses of the government; 13th, to impose taxes, contract loans, and direct every thing relating to the revenue; 14th, to establish a plan of public instruction, and direct the education of the prince of Asturias; 15th, to protect the *political* liberty of the press; 16th, to enforce the responsibility of the secretaries of state, and other persons in office.

Laws may be proposed, in writing, by any one of the deputies. Two days after the motion, the bill is to be read a second time. It is then determined whether the subject is to be debated, or to be referred to a committee. Four days after the bill has been voted worthy of discussion, it is read a third time, and a day is appointed for the debate. A majority of votes decides the fate of the bill; the members present on these occasions must exceed half of their total number by one.²

The powers of the king are, 1. To suspend the passing of a law, by withholding his sanction. He can exercise this power against any decree of the Cortes for two consecutive sessions; but is compelled to give his assent if the same law is passed by three Cortes successively. 2. The executive power resides exclusively in the king, and extends to whatever relates to the preservation of public order in the interior, and to the external security of the state, according to the constitution and the laws. The privileges and duties of the executive are thus detailed in the constitution. The king may issue decrees, regulations, and instructions, for the more effectually enforcing of the laws; it is his duty to watch over the administration of justice; he declares war and makes peace, under the control of the Cortes; he appoints judges to all the civil and criminal courts, on the presentation of the council of state; all civil and military employments are of the king's appointment; he presents to all bishoprics, ecclesiastical dignities, and benefices which may be in the gift of the crown, all by the advice of the council of state; the king is the fountain of honour; the army and the navy are at his command, and he has the appointment of generals and admirals; he has the right of coinage, and the privilege of impressing his bust on the metallic currency of the realm; the king can propose new laws, or amendments to those in existence. It belongs also to him to circulate or withhold the pope's rescripts and bulls. He can choose and dismiss his own ministers.

The following checks are imposed on the king's authority by the constitution.

1. The king cannot prevent the meeting of the Cortes at the periods fixed by the constitution, neither can he dis-

¹ The Cortes were separated into two bodies in 1836, and the election was made direct, not indirect.

² Some alteration in the powers of the sovereign was made in 1836, when this constitution was adopted. It was then decided, that the crown should have an absolute veto in the enactment of laws, and should likewise have the power of convoking, proroguing, and dissolving the Cortes; but in the latter case to be under the obligation of assembling others within a given time.

History. solve them or disturb their sittings; his advisers and abettors in such attempts are guilty of treason. 2. If the king should quit the kingdom without the consent of the Cortes, he is understood to have abdicated the crown. 3. The king cannot alienate any part of the Spanish territory. 4. He cannot abdicate the crown in favour of his successor without the consent of the Cortes. 5. He cannot enter into any political alliance, or make commercial treaties, without the consent of the Cortes. 6. He cannot grant privileges or monopolies. 7. The king cannot disturb any individual in the enjoyment of his property, nor deprive him of his personal liberty. If the interest of the state should require the arrest of any individual by virtue of a royal order, the prisoner must be delivered over to a competent tribunal within eight and forty hours. 8. The king cannot marry without the consent of the Cortes; he is supposed to abdicate the crown by taking a wife against their will.

The council of state is composed of forty individuals, viz. two bishops, two priests, and four grandees; the other thirty-two must not belong to any of these classes. The members of the council of state shall be chosen by the king, out of a triple list presented to him by the Cortes. The councillors of state cannot be removed without a trial before the supreme court of justice. Their salary is fixed by the Cortes. The functions of this council of state are to advise the king on all important matters of government, and especially upon giving or refusing his sanction to the laws, declaring war, or making treaties. The king, besides, cannot bestow any ecclesiastical benefice, or appoint any judge, but at the proposal of the council of state, who, upon every vacancy, are to confine his choice to one out of three individuals, whose names they are to lay before his majesty.

The laws for the security of personal liberty are these: 1. No Spaniard can be imprisoned without a summary process, in which he is credibly charged with the infraction of some law that subjects the offender to corporal punishment; 2. the arrest cannot take place without the warrant of a competent judge; 3. prisoners are not to be examined upon oath; 4. the gaoler shall keep a register of the prisoners, expressing the warrant, and the alleged cause of his confinement.

The rapid series of misfortunes which had shaken the imperial throne of France to its foundations opened the way for the return of the captive Ferdinand to Madrid. The constitutionalists looked forward to his appearance in the country with no favourable eye, and the arrival of despatches from him to the regency threw them into great consternation. Ferdinand announced that he had concluded a treaty with Napoleon. This assumption of absolute power on the part of the king, without the knowledge of the Cortes, was aiming a direct blow at their authority, and violating the constitution recently established; and they accordingly rejected the treaty. They likewise suspended the king from the exercise of all power till he should take the oath which the new constitution prescribed. He entered the Spanish territory on the 24th of March 1814, and took up his residence at Valencia. On his way he had not been slow to discover that the lower orders were in general indifferent to the constitution. The fact is, the new political principles had scarcely struck root among the people; and with a very considerable party, consisting of grandees, dignitaries of the church, and others, the king was still absolute, and these flocked around their master. In the Cortes itself there was a strong body opposed to the new order of things. A petition, signed by sixty-nine members, was presented to the king, in which the Cortes was described as a mere tool

in the hands of a republican party, without freedom of debate, and acting under the control of a mob regularly hired to take possession of the galleries. Nothing, therefore, could be more favourable to Ferdinand's resuming absolute power. Accordingly, on the 4th of May 1814, a decree was solemnly promulgated, in which the Cortes were declared illegal, and all their laws consequently rescinded. Some of the leading members were arrested, as a prelude to what was shortly to happen. Under their usual leaders, the priests, the lower orders broke out into fierce demonstrations of joy when the news of these events reached the chief towns, and the king proceeded in a sort of triumph to Madrid. Further arrests of the deputies of the late Cortes took place; property was sequestered and papers were seized; judges were appointed to try obnoxious members; but justice proving too tardy for the king's eager spirit of revenge, he himself pronounced sentence on the prisoners in a wholesale manner, in open defiance of all law and justice. A few were capitally punished, and a great many more were consigned to dungeons. The inquisition was restored, and was urged to exert its powers against all persons suspected of liberal opinions. Monks became once more the sole directors of the king's conscience, and the reign of absolutism and bigotry was completely restored.

But these arbitrary acts roused the dormant spirit of the Spanish people, and a revulsion of feeling was the consequence. In vain did the court party silence the press or bribe it into their service; facts which could not be concealed from the people daily pleaded the cause of liberty. Bribery and venality were soon observed to prevail around the throne; the treasury was completely drained, and the army remained unpaid; while, to add to the difficulties and dangers of Ferdinand's position, armed bands of guerillas, now become organized banditti, swarmed over the country, setting the helpless magistrates at defiance, and committing all sorts of atrocities. Free-masonry was abolished, and effectually kept in check; but a far more dangerous society, the members of which assumed the name of *Comuneros*, was secretly formed, and, in spite of the inquisition and its emissaries, held meetings in most of the principal towns, and kept up an active correspondence among their lodges. The constitution was publicly burned; but this served only to spread disaffection, and to give it an importance in the eyes of the people which it did not formerly possess. Cadiz having been fixed on as the head-quarters of the liberals, a regular plan for the overthrow of the government was there formed, and its secret influence was extended throughout the provinces. Our limits do not permit us to mention the numerous conspiracies which were discovered, and quenched in blood. They were sufficient to alarm any monarch but one wholly abandoned to the guidance of weak, wicked, or fanatical counsellors. Those who ventured to remonstrate with the king were banished or thrown into prison. The promise which he had made of granting a constitution founded on liberal principles remained unfulfilled, and for six years (1814-1820) Ferdinand reigned with absolute power. During that time there had been no less than twenty-five changes in the ministry, mostly sudden, and attended with severities. They were produced by the influence of the *camarilla*, or individuals in the personal service of the king. Every attempt to save the state was frustrated by such counsellors; and the overthrow of the government, now apparently inevitable, became accelerated by the loss of the American colonies.¹

The army was the instrument of its fall. Amongst the officers several conspiracies had been organized for the restoration of the new constitution, at the head of which were

¹ It is unnecessary to do more in this place than merely allude to the revolution in the Spanish colonies of South America, which broke out in 1808, and finally terminated in the achievement of complete independence. Under the heads MEXICO, PERU, PLATA, &c., the revolutions in the various provinces will be found described.

History. Porlier, Mina, Lacy, and Vidal. Mina had succeeded in making his escape, but the others were taken and executed, their friends at the same time being put to the torture or thrown into prison. But these severities had no effect in repressing the discontent of the army; for the cause which immediately produced it was not removed,—the arrears due to the troops still remained unpaid. The money which might have been employed for this purpose was foolishly lavished in fitting out an expedition to destroy the liberties of the revolted South Americans: by a singular destiny it became the instrument of the overthrow of despotism at home, and the restoration of Spanish freedom. The troops which were to embark in the autumn of 1819, were indisposed to the American service; and the officers, favourable to the constitution of the Cortes, took advantage of this state of feeling to effect their own purposes. Whole regiments had determined not to embark; and the commander himself, O'Donnel, count del Abisbal, was in the secret. But he basely betrayed the cause, and had the principal conspirators arrested in front of the troops. For this devotion to despotism he was rewarded by the court party by being removed from the command of the expedition. Such ungrateful conduct towards a man who had forfeited his honour to save them, could not fail to bring the *Serviles*, as they were designated, into general contempt. A favourable opportunity soon occurred for the liberals carrying into execution the same plan which had failed through the perfidy of O'Donnel. The yellow fever having made its appearance at Cadiz, the safety of the troops which were there assembled demanded that they should be removed to some distance, thus leaving the members of the secret societies and other patriots at liberty to prosecute their schemes without fear of violent interruption. The embarkation of the troops had been fixed for January 1820; but on the first of that month, Riego, who had been placed at the head of the insurrection, gained over several battalions, and proclaimed the constitution of 1812. He arrested Calderon, the successor of O'Donnel; and finally joining Quiroga, a liberated patriot, and at the time in command of some troops, the combined force, amounting to 5000 men, marched on La Caracea, which was occupied. They had previously taken possession of La Isla. But still the country showed no disposition to second this bold movement of the army. In vain Riego led a flying column through the provinces, proclaiming the constitution, and expecting support from the inhabitants; few or none joined him. But several fortunate circumstances which occurred at this time materially contributed to the success of the insurrection. Mina, who had been obliged to fly to France, entered the Spanish territory of Navarre on the 25th of February, and a numerous band immediately surrounded his standard. Risings simultaneously took place in different quarters in favour of the constitution, which was publicly proclaimed in Galicia, Saragossa, Valencia, Murcia, Granada, and many other places. General Freyer, who had been appointed to the command of the troops in Seville, was himself obliged to publish the constitution in that city.

These insurrections could not fail to appal the weak, ignorant, and unpopular party which surrounded the throne. Ferdinand himself saw no general of sufficient ability or loyalty to be trusted with the command of a large army, which could soon have been concentrated, for there still existed fidelity among a sufficient number of the troops. It was however an expiring feeling, which could only have been re-animated by a great leader, but which, in the present destitution of the country, a mere breath might extinguish. And it was extinguished. Ferdinand was abandoned by his troops. Even O'Donnel, who had acted the part of traitor to the liberal cause, became one of its principal supporters. At Ocana he proclaimed the constitution; an event which produced a great sensation in Madrid. The

royal palace was surrounded by a crowd, who called on Ferdinand to accept the constitution, and he now found that no alternative was left to his choice. The humbled monarch appeared at the balcony, holding a copy of the constitution in his hand, as a pledge of his readiness to swear to its observance. This occurred early in March 1820. To give efficacy and legality to the restoration of the constitution, it was necessary that the Cortes should be convoked, and the oath of the king to uphold the new order of things taken in their presence. The Cortes assembled on the 9th of July, and all the formalities were regularly observed. Meanwhile the constitutional system had been put into complete operation. During its proclamation at Cadiz, a bloody and disgraceful transaction took place; some of the royal troops present wantonly fired on the unarmed multitude, and about 500 were killed or wounded. The inquisition was abolished, as inconsistent with it, the state-prisoners were liberated, and new ministers were appointed. In place of the Council of Castille, and that of the Indies, a supreme judicial tribunal, with appropriate subordinate courts, was established; national guards were organized in the provinces, and the municipal authorities were made to conform to the constitution.

The meeting of the Cortes of 9th July, and their subsequent proceedings, mark the establishment of a new order of things, destined however to be of short duration. This assembly acted with extreme moderation, the measures of retaliation being infinitely less severe than those which followed the king's triumph over the constitution. The members strove to temper the violence of the liberals, and endeavoured to restore the *afrancesados* (those who took the oath to support the French dynasty) to their rights, to counteract the machinations of the *serviles*, and to heal the wounds of the country. But some of their proceedings were characterized by less judgment and humanity. The suppression of many of the convents and of the *majorates*, the banishment of the nonjuring clergy, and some other of their measures, excited discontents. Various parts of the country became disgraced by popular excesses, while on the frontiers of Portugal the royalist party formed a junta for restoring the privileges of the crown and the church. Conspiracy and openly avowed disaffection to the new order of things spread so widely, that when the second session of the Cortes opened in April 1821, the country was declared to be in a state of danger. The command of the army having been intrusted to Morillo, quiet was in some measure restored; but still it was found necessary to summon an extraordinary meeting of the Cortes in September. Spanish affairs in America had now assumed their gloomiest aspect; and the government wished to compromise the matter by acknowledging America as a kingdom independent of Spain, but united with her under a common sovereign, Ferdinand VII. Such an absurd proposal was rejected with scorn. The absolutists, although beaten everywhere by the troops of the government, could not be entirely suppressed; and even the adherents of the constitution began to complain of the weaknesses and mistakes of the ministry. The Cortes requested the king to appoint abler men; and to this he reluctantly yielded in 1822. Notwithstanding the errors of the Cortes, considering that the king was with them, and that his brother Carlos, although approving of the conduct of the absolutists, had not ventured to join them, it is probable that the struggles, after continuing for a few years, might have ended in a compromise, had not the whole power of France been thrown into the scale of the *serviles*.

The events which immediately preceded Ferdinand's restoration to absolute power, and the complete annulment of all the acts of the Cortes, were so various and complicated, that, if fully detailed, they would of themselves more than occupy all the space within the limits to which this

History.

History. outline of Spanish history must be confined. Into particulars, therefore, we shall not enter; only the most important transactions can be noticed. Disaffection to the government in the southern provinces, where a strong body of French troops was stationed as a sanitary cordon during the prevalence of pestilence in Spain, terminated in open revolt. The national guards were called out to suppress it, and they were everywhere victorious; but the pecuniary resources were chiefly in the hands of the supporters of despotism. In Madrid an occurrence took place in July 1822, which threatened the most disastrous consequences. This was a daring attempt of the friends of absolute government to overthrow the constitution. They were supported by the royal guards, while the national guards were ranged on the popular side. A conflict took place, in which nearly the whole of the royal guards were cut off. But insurrection, although thus suppressed in the capital, still prevailed to an alarming extent in Biscay, Navarre, and Catalonia, where armed bands, under the name of apostolical troops, *feotas*, or soldiers of the faith, committed revolting cruelties. Near the French frontier, and probably under French influence, the absolutists appointed a regency, which issued orders in the name of the "imprisoned" king, as they thought fit to call Ferdinand, although he had recently, under no compulsion, but in the most voluntary manner, again declared his adherence to the constitution. The avowed object of this regency was the restoration of every thing to the state in which it had been prior to the 7th of March 1820. But this band of outrageous serviles, unsupported by the nation, was compelled to fly to France in November 1822. The foreign relations of Spain now fell into a state of dreadful disorder; and the principle of armed intervention pronounced by Austria, Russia, and Prussia, in relation to this unhappy kingdom, was threatened to be acted upon by France. The restoration of Ferdinand to the full enjoyment of sovereign authority was demanded by the four powers named, while England advised the Cortes to yield, and offered her mediation. But the Spanish government repelled with indignation this attempt of foreign powers to interfere in its affairs. The consequences were the recall of the foreign ambassadors by their respective courts, and the march of 100,000 French soldiers across the Bidassoa. The duke of Angoulême, by whom this army was commanded, established a junta, consisting of Eguia, Calderon, and Erro, who formed a provisional government, declaring the king the sole depositary of sovereign power, and that no change in the government should be recognised but such as the king should make of his own free choice. All the decrees of the Cortes were declared void; in short, the object of French interference was simply to restore the reign of absolute power. Unfortunately the Cortes had no ally. The relations of Portugal to Great Britain did not allow her to conclude a defensive treaty with Spain. Britain remained neutral; but the exportation of arms and ammunition to Spain was allowed, and, in parliament, Canning called the attempt of the French unjust, and wished the arms of the Cortes success; an expression of sympathy which led the Spaniards for a time to hope that Britain would take a part in the war. Ferdinand, for greater safety, had removed to Seville, and on the 23d of April 1823 he formally declared war against France; but he in vain called on the nation to support the constitution. The great mass of the people were completely under the influence of the most bigoted priesthood in the world, who of course were absolutists, and hailed the arrival of the French; the adherents of the constitution were confined to the educated class, the army, and the inhabitants of cities. The Spanish army might be equal in strength to that of the French, but a considerable part of it was disposed in garrisons and fortresses, scattered over a large surface of country. The military operations of the

French, during their advance upon Madrid, were the siege and capture of several strong towns, and a few partial engagements, in one of which, at least, that of Logroño, they were defeated. The southern provinces, where the absolutists had always a preponderancy, were occupied by the invaders with hardly any resistance; but in Lower Catalonia, where Mina commanded, they were kept in check for a considerable time. The main body of the French army under Angoulême hastened to the capital, which was occupied on the 24th of May. One of the first steps taken was to appoint a regency, which put every thing on the same footing as before March 7, 1820. But the regency had no pecuniary resources, and no power, if they had the will, to prevent the furious ebullitions of party hatred. The Cortes had in vain tried to excite a general guerilla war; it was but too plain that the mass of the people, at once miserably ignorant and furiously bigoted, without any just notions of what rational liberty was, or in what the new constitution consisted, were content to surrender themselves entirely to the guidance of the priesthood, and consequently everywhere opposed the constitutionalists. Their hatred was still further increased by the seizure of all the property of persons of the opposite party, by a large forced loan, and by the coining of the superfluous church plate, to which measures the want of money compelled the Cortes to have recourse. The war had now spread from the south to the north over the whole breadth of the land, and was actively prosecuted in Andalusia and Estremadura. An attempt at mediation on the part of the English ambassador, Sir W. A'Court, failed; and the king having refused to go to Cadiz, the Cortes, acting on that part of the constitution which provides for the moral incapacity of the sovereign, appointed a regency with royal powers. We cannot regard this proceeding in any other light than as a gross indignity offered to the king, and most impolitic at the time. However, Ferdinand accompanied the Cortes to Cadiz, and the regency ceased to exist. On the other hand, the members of the Cortes who had declared the king morally incapable, were denounced as traitors by the regency of Madrid, which now became recognised by foreign powers, Austria, Prussia, and France, as the only legitimate government of Spain.

Meanwhile the war was briskly carried on, but nothing would induce the people to join the constitutionalists, who accordingly were gradually driven from stronghold to stronghold, although in some places they made a gallant resistance. Defection among the officers of the army materially contributed to the downfall of their cause. Morillo and Sarsfield were among the deserters. The regency of Madrid conducted themselves in a cruel and outrageous manner towards the friends of the constitution, notwithstanding the strenuous efforts of the French generalissimo to restrain their fury. The duke of Angoulême took possession of the city of Cadiz on the 4th October 1823. Previously to this, the Cortes had reinvested Ferdinand with absolute power, and requested him to remove to the French head-quarters, where he was received with becoming pomp. The first measure of the king was to declare all the acts of the constitutional government from March 7, 1820, to October 1, 1823, null and void, on the ground that during that period he was acting under compulsion. The war terminated in November; and on the 22d of that month the duke of Angoulême took his leave of the army of the Pyrenees. Among the crowds of fugitives were Mina and the count of Abisbal; and among the victims capitally punished was Riego, who suffered at Madrid on the 6th of November.

The party which now succeeded to power, although weak from want of means, was powerful enough to exercise a persecuting and vindictive policy towards the former partisans of the constitution. The French wished to secure

History.

History. mildness and moderation, but the bad faith of the Spanish government frustrated these objects. To restrain the violence of party fury, which so widely prevailed, a treaty was concluded with France, by which that power agreed to maintain a large military force in the country, until the Spanish army could be organized. This was certainly a wise measure in the circumstances; for Spain, if left to itself, would probably have fallen into irretrievable confusion. It was divided by two parties, who mortally hated each other; and the bonds of society, already shaken loose by years of war and unrestrained licentiousness, required little more to dissolve them altogether. The reports from the provinces were appalling; the treasury was empty; home and foreign credit were alike destroyed; and trade and commerce were paralyzed. The personal moderation of the king led to the formation of a plot by the absolutists, to compel him to abdicate, and to raise his brother Carlos to the throne. This was the origin of the Carlists, who make so conspicuous a figure in the sequel. An attempt to restore the inquisition was happily frustrated. In May 1824, a decree of amnesty appeared; but it was a mere mockery, for it contained so many exemptions, that those who were to enjoy its benefits seemed rather to form the exception than the rule. The year 1825 was disturbed by several insurrections of the Carlists, which were attended with numerous executions. The independence of the American colonies was recognised by foreign powers, but Spain herself did not acknowledge it till the year 1836. The general interruption of commerce and industry, with the flight of many persons of property, occasioned much distress. The disturbances continued for some years, attended with the same marks of feebleness on the part of the government, and a continuance of general distress. It was a period of terror for the liberals, who were plundered and imprisoned on the slightest pretexts. The army, purged of all officers suspected of liberalism, was recruited by a motley throng of adventurers, friars, smugglers, mechanics, publicans, and muleteers, who had been officers in the guerilla bands of Catalonia and Navarre. The ranks being replenished in this manner, the French troops were enabled to evacuate Spain in 1828. Some insurrections, which had broken out during the preceding year, were suppressed without much trouble; and in spite of the arbitrary rule of the Carlists, their tortuous policy, and their open violence, the country began to show some symptoms of improvement.

In May 1829, Ferdinand lost his queen, and on the 9th of November following, her place was supplied by a Neapolitan princess, Christina Maria. Unblessed with issue by his three former marriages, the hope and the desire of having a child of his own to inherit his honours and preserve the throne to his dynasty, probably hastened the nuptials of Ferdinand. The French revolution of 1830 caused much less sensation in Spain than might have been expected. The fact is, the liberal party had been so devoured or dispersed by the sword, the scaffold, exile, and the dungeon, that in the country itself it was not powerful; but a rash and ill-judged attempt in the constitutional cause was made from without. General Mina assembled a body of refugees and others, and invaded the Basque provinces; but they were speedily repelled, and sought refuge in France. Meanwhile, some events of momentous importance had taken place in the royal family. The Infant Don Carlos was presumptive heir of the throne; the succession to the Spanish crown had been subjected to the Salic law by Philip V., so that, as matters stood at present, no daughter of the reigning king could interrupt its descent to his brother. The queen of Ferdinand was about to make him a father, and in order to secure the crown to his own child, should the issue prove a female, he resolved on revoking the Salic law, which excludes females. It is important to observe, that, in 1789, Charles IV. issued a pragmatic sanction, hav-

History. ing the force of law, and establishing the regular succession to the crown of Spain in females as well as males. The Cortes of 1812 likewise solemnly revoked the law of Philip V., and re-established the old law of the Partidas. But as Ferdinand had annulled the acts of that assembly, and as the decree of Charles IV. might be cavilled at by the fierce and intolerant party who wished that Carlos should succeed to the throne, the king obtained the records of the Cortes of 1789 regarding the succession, and on the margin opposite the decree of Charles IV., with his own hand, wrote a decree to the same effect. The minister, Calomarde (a Carlist at heart), remonstrated with the king against its publication; but Ferdinand was firm, and ordered the resolution to be carried into effect. In compliance with this demand, the whole was forwarded to the council; and in the gazette of the 6th of April 1830, the edict was published to the world. It was likewise regularly proclaimed in the streets of Madrid with the usual formalities. Ferdinand's foresight was justified. The infant with which the queen presented him was a daughter, born on the 10th of October, and christened Isabella Maria Luisa.

But the Carlists did not wait for the expected birth of the heir to the throne to show how terribly the publication of the decree had staggered them. They rushed into hasty plots against the government, which were detected before they were ripe for execution; and in various ways showed their chagrin and irritation. In order to render the succession still more secure, Ferdinand called a meeting of the Cortes, before which the edict of Philip V. was again repealed, and his daughter, the Infante Isabel, recognised as princess of the Asturias. An insurrection broke out in Cadiz in 1831, at the head of which was General Torrijas. It was soon quelled, and the leader, with fifty-three companions, fled to Malaga, where they were taken prisoners, and all shot in cold blood. The other events of this year are unimportant, with the exception of a sudden illness of the king, which so excited the hopes of the Carlists, that they strenuously urged their master to take advantage of the circumstance, and at once seize the crown. This remarkable fact shows with what spirit they were animated. It was not a love of justice, but ambition, and a spirit of vindictive hostility to the constitutionalists, who now began to be tolerated, that instigated them to attempt the exaltation of Carlos to the throne, and that at all hazards, even before he possessed the semblance of a claim to it; for while Ferdinand lived, by what right could he grasp at his sceptre? Yet his partisans extol his magnanimity in refusing it at this time.

In the course of the year 1832, Ferdinand had an alarming relapse of his disease, during the paroxysms of which a transaction took place of the utmost importance in itself, and which has been very differently represented by different parties. It was the signing of a decree by which he restored the Salic law to full operation, and the further confirming the disinheriting of his daughter, by annulling his testament in her favour. It is certain that the ministers strenuously urged him to adopt this measure; and that they were under Carlist influence, is no less certain. Every thing was accomplished to their wishes; the document was signed and properly secured, and the king appeared to have fallen into the sleep of death. His dissolution indeed was announced; but, contrary to all human expectation, the disease took a favourable turn; all symptoms of immediate danger disappeared, and consciousness and understanding were restored to Ferdinand. The use which he made of the lucid interval thus vouchsafed to him, was to dismiss his ministers, to appoint the queen regent during his illness, and to undo what he had lately done regarding the succession, thus restoring to his daughter her right to the throne. The decree to this effect was issued on the last day of the year. The former ordinance, he declared, had been extort-

History. ed from him, not only when he was in the agonies of expected death, but under false misrepresentations that all Spain demanded it, and that the inviolability of the monarchy required it; whereas it had only been desired by an ambitious and unscrupulous faction, and was opposed to the fundamental laws of the kingdom. A more liberal ministry was formed, and some liberal measures were adopted; high expectations were raised that milder times were at hand, and the funds in Madrid rose ten per cent. Early in 1833, Ferdinand was able to resume the reins of government. On the 20th of June he assembled the Cortes to swear allegiance to his daughter, and do homage to her as their future sovereign. This solemnity was performed with great pomp in the church of the royal monastery of St Jerome. Don Carlos refused to take the oath; but previously to this he had taken up his residence in Portugal, where his nephew was playing the same desperate game which he himself was about to undertake. Ferdinand survived the ceremony of the *jura* only a few months. He expired on the 29th of September 1833, leaving a will, in which he appointed his daughter Isabella heir to the crown, and her mother regent during her minority.

No sooner was Isabella II. proclaimed queen, than Don Carlos announced his claim to the throne, and the flames of civil war burst out in the northern provinces, where his partisans, assembled in great numbers, stood ready armed for the contest. Of the bloody and protracted struggle for the throne which ensued, we can afford room for few details; indeed, an account of the numerous battles, skirmishes, sieges, and other warlike operations, would prove a very uninteresting and monotonous portion of the modern history of Spain. Isabella was acknowledged without opposition throughout all the provinces of Spain, and by the leading powers of Europe. The question of the Spanish succession, apart altogether from the bloody war to which it gave rise, has been keenly agitated in this and many other countries. It may be briefly stated as follows. Carlos's right rests upon the Salic law, which had never the force of law in Spain. The Salic law was not the ancient rule of succession; it was first introduced by the Bourbon Philip V., the great-grandfather of Don Carlos. Females could always succeed in Castille, Leon, and Portugal. It was by marriage with the heiress of Navarre that a king of France obtained a claim to that kingdom; and although females were excluded in Aragon, yet it was through a princess that its inheritance passed to the counts of Catalonia. It was by the right of female succession that the house of Austria reigned in Spain; it was by the same right that the Bourbons themselves occupied the throne. It formed a part of the *Partidas*, or system of constitutional law, which Philip swore to observe on his succession to the throne. The Salic law, on which Carlos grounds his claim, could only be established in two ways; by the old forms of the constitution, or by the despotic will of the sovereign. If the advocates of Don Carlos take their stand on the former ground, the answer is, that the forms as well as the substance of the constitution were violated when Philip V. established his law of succession; and that, conscious of its invalidity, he did not register it in the form usual with similar acts; while again, if we pass over the Cortes of 1789 as secret and irregular, we have the Cortes of Cadiz in 1812, which abolished the decree of Philip, and restored the ancient law of the *Partidas*. But Ferdinand having annulled the proceedings of this body, its re-establishment of the right of female succession must fall to the ground with its other decrees. There is however Ferdinand's own decree, constituting his daughter his successor, which was just as regularly sanctioned by the Cortes as Philip's law of succession. If, on the other hand, the sovereign is to be regarded as despotic in Spain, the question is at an end; for even Carlos must acknowledge that Ferdinand had a right

to regulate the succession according to his own royal pleasure. This view seemed to have been taken by the king's confessor, and his minister Calomarde, when, during his dangerous illness at La Granja in 1832, they induced him to sign a new will, settling the crown on Don Carlos. Ferdinand's recovery disconcerted their plan; but their effort plainly shows that the partisans of Don Carlos at that time felt that the Salic law was a very weak support to their favourite's claims. The transaction by which Ferdinand (supposed to be on his death-bed) transferred the crown to his brother, is admitted by the Carlists to have been a perfectly legal proceeding. Can the subsequent transaction, by which, under exactly similar circumstances, the king appointed his daughter his successor, be considered otherwise than as an equally legal proceeding? If the constitution be referred to, the question is decided against Don Carlos; the will of the sovereign is against his claim; and, what is of yet more consequence, as the event has shown, the will of the majority of the nation is against him.

History. It was in the northern provinces, in Navarre, Guipuscoa, Biscay, and Alava, that the strength of Don Carlos lay. Here he was immediately proclaimed in several towns by the title of Charles V., and bands of Carlist guerillas assembled to maintain his right to the throne. He himself still hovered a fugitive on the frontiers of Portugal, his movements being closely watched by a royal force under General Rodil. Another strong division of the queen's army, under General Sarsfield, marched against the disaffected provinces. The Carlists retired before him; Bilboa and other towns were occupied and garrisoned; the constitutional party was restored in several places where it had lost ground; and the insurrection seemed at first to have been happily put down without much loss. But early in 1834 the affairs of the Carlists assumed altogether a new aspect. Hitherto their operations were carried on in an unconnected manner; this system was now exchanged for one of steady unity of design. Indeed so numerous were the adherents of Don Carlos in the north, that there was only required a firm hand to seize the reins, control local jealousies, and direct aright the energies of the provinces. Such a man was Thomas Zumalacarreguy, who now assumed the chief command of the Carlists. He was admirably skilled in the desultory warfare of these provinces, and well acquainted with the country and with the character of the inhabitants. By his activity and enterprise he repeatedly inflicted severe blows upon the forces of the queen, or the *Christinos*, as they were generally called. His method of fighting was to surprise the enemy in an unprotected position, and cut off as many of them as he could before they recovered from their panic. His troops would then suddenly separate and fly, but only to unite again at a predetermined point some miles in the rear. By this mode of warfare he caused great loss to the *Christinos*, while his own small band suffered little. The *Christino* army under General Rodil, who had now obtained the chief command, might amount to 20,000 men, and was thus sufficiently strong at least to have confined Zumalacarreguy to the mountains; but it was greatly reduced by several thousand troops having been distributed among a number of petty fortresses, most of which, one after the other, fell a prey to the Carlist chieftain. It was further weakened by being divided into different corps and scattered over the country. Rodil found it necessary to resign the command, which now devolved upon Mina, from whom much was expected. Nor did he disappoint the hopes which were formed of him. Just before his appointment, Generals O'Doyle and Asina had severally been defeated with great loss by Zumalacarreguy, which occasioned much alarm at Madrid, and loud outcries against the ministry. But the old warrior, though broken by sickness and infirmities, restored confidence by making head against the hitherto victori-

History. ous Carlists, and bringing victory to the standards of the queen.

In the mean while, Don Carlos, after paying a short visit to England, made his appearance in Spain; and his presence among his partisans greatly strengthened his cause in the northern provinces. France and Britain had acknowledged Queen Isabella II. These two powers, along with Portugal, entered into a treaty with Spain, the conditions of which quadruple alliance were, that France should watch the frontiers, so that the insurgents might receive no aid from that country; that Britain should supply such arms and munitions of war as the Spanish government should stand in need of, whilst at the same time she should guard the northern ports of Spain, so as to prevent the insurgents from receiving any assistance in men, money, or ammunition, and also assist the queen with a naval force; and that Portugal should co-operate by every means in her power: but that country was at the time in too embarrassed a situation to render any efficient assistance. As soon as the arrival of Don Carlos in Navarre was known, the four powers who had been parties to the treaty renewed its stipulations, in respect that its object had not yet been attained. This imparted confidence and vigour to the cabinet of Madrid, of which it stood greatly in need. A variety of measures occupied the attention of government during the year 1834, not the least important of which was the plan of a new charter or constitution. It is quite unnecessary to enter into any details of what the Cortes proposed should be done, as every thing was overturned and put upon a new footing by a revolution which occurred two years afterwards. The financial state of Spain, particularly the large debt which the government owed to foreign nations, formed a subject of protracted discussion. Doubts were raised as to whether a part of it was legitimately owing; but the debates in the Cortes terminated in the whole being recognised as justly due. This contributed to restore the credit of Spain in foreign money-markets, where it had been greatly shaken, and enabled the government to contract for a new loan. Another measure of importance which engaged the attention of the Cortes, was the passing of a bill of exclusion from the throne against Carlos and his descendants. During the year the ministry had undergone a complete change, chiefly through the instrumentality of a popular leader of the name of Llauder. Zea was superseded in the office of prime minister by Martinez de la Rosa, supposed to be a person of more liberal predilections.

The military operations of 1835 were prosecuted with great vigour on the part of the Carlists. Several important towns and fortresses fell into their hands, and siege was laid to Bilboa, the capital of Biscay. After sustaining a furious bombardment for several days, the place was relieved, principally through the instrumentality of some British gunners under Lord John Hay, commander of a ship of war then on the coast of Biscay. It was during the attack on Bilboa that Zumalacarreguy received the wound of which he died on the 23d of June. The death of this chief threw a gloom on the affairs of Don Carlos: it was the severest loss which his cause had sustained, and he never properly repaired it. Among the Christinos this event diffused a joy and hope which they made no efforts to conceal. Worn out by long service, by age, and by disease, the veteran Mina resigned the command, which ultimately devolved upon General Cordova, under whom was the celebrated Espartero. The Spanish government having been permitted to levy a body of mercenaries in Great Britain, several thousand recruits were raised in this country, and were led to the theatre of war in Spain under the command of General Evans. The British legion soon took an active part in the war, and distinguished itself upon various occasions. The Carlist army, although it aban-

History. doned the siege of Bilboa, still continued in the neighbourhood, prepared to take advantage of circumstances. An opportunity soon occurred for attacking the Christinos at the village of Arrigoriaga, which they made an attempt to pass. The royalists were driven back with considerable loss, and this check for the time interrupted the movements of Cordova's army. On the other hand, the Christinos laid claim to more than one victory gained over their enemies; but these doubtful and unproductive skirmishes, which in the flush and enthusiasm of triumph were magnified into decisive battles, are too insignificant to require a detail in this place. At the close of 1835, matters stood much as they did at the commencement of the year. But the war was now carried on with more humanity than formerly. A strong remonstrance on the part of the British government, against the barbarous practice of putting prisoners to death, had the desired effect, at least for a time, of staying the effusion of blood in this inhuman manner.

Those parts of Spain exempt from the horrors of war, were for the most part subjected to the scourge of political anarchy. The new government of the queen-regent had been founded on an abandonment of the old system of unmitigated despotism. Her daughter's throne was to be identified with more liberal institutions, and was thus to be protected by all political reformers, all who were inimical to absolutism. But the extent to which the old system was to be abandoned, and the form in which a popular government was to be established, were questions regarding which every possible diversity of opinion prevailed. The unquiet elements thus at work showed themselves first in a military revolt, and then in the revolt of several provinces, in which the democratic party sought to usurp the powers of government. For a time they set the lawful authorities at defiance, for the government of Madrid was helpless. Even here disaffection had spread to a most alarming extent, the urban militia having openly revolted. In vain were royal decrees issued, and strong measures put in force to repress the disturbances; an open war between the government and numerous sections of the liberals seemed on the eve of breaking out. Fortunately this was averted by a change of the ministry, which was loudly demanded by the factious opposition. The life and soul of the new ministry was Mendizabel, a man of great vigour, and very popular among the people, on account of his liberal principles. He condemned the repressive measures which had been acted upon, adopted a more lenient system of dealing with the malcontents, and proposed various alterations in the constitution, the mere mention of which sufficed to restore the country to comparative tranquillity. But all the deliberations of the ministry and the Cortes were rendered abortive by the military revolution which broke out at Malaga on the 25th of July 1836. The object of the ultra liberals had uniformly been the restoration of the constitution of 1812. Without this no change of ministers could satisfy them, and no vigilance on the part of government could prevent them from covertly prosecuting their designs. It was with the national guard that the revolt originated. In Malaga the governor was assassinated, and a junta was appointed to proclaim the constitution. Intelligence of these events spread throughout the country with the greatest rapidity. Cadiz and Saragossa took up the signal nearly at the same moment; and they were instantly followed by Seville, Cordova, Granada, and Valencia. At length the capital itself joined the insurgent cities; and on the 13th of August the queen, now deserted and helpless, was compelled to issue a decree, promising the restoration of the constitution of 1812. But all men who were reasonable and honest in their politics felt and admitted that some alterations in that code were quite indispensable. The Cortes accordingly appointed a committee to consider and propose

History. such alterations as were necessary and advisable; and this they accomplished in a highly satisfactory manner. The changes recommended and finally adopted by the Cortes were, 1st, that the part of the constitution which contained mere regulations and forms, and regarded organic bodies and laws, should be entirely suppressed: 2dly, that instead of the Cortes continuing to form, as they did under the constitution of 1812, only one body, they should now consist of two bodies, differing from each other in the personal qualification of their members, &c. but neither to be hereditary nor privileged: 3dly, that the crown should have an absolute veto in the enactment of laws, and should likewise have the power of convoking, proroguing, and dissolving the Cortes; but in the latter case to be under the obligation of assembling others within a given time: 4thly, that the election of members of the Cortes should be direct, and not indirect, as established by the constitution of 1812.

While Spain was thus undergoing the most momentous political changes, the very existence of the queen's government was threatened by the Carlists, who were making alarming progress in the very centre of the kingdom. During the early part of the year the Christinos attacked the position of the Carlists at Arlavan, but with so little success that they were compelled to make a retrograde movement. However, early in May, the British legion, under General Evans, gallantly carried the Carlist lines before St Sebastian; but unfortunately this victory, like many others gained, was productive of no important result, chiefly through the sloth and inactivity of the Spanish generals. The circumstance which created the great alarm to which allusion has been made, was the march of a large body of Carlists under Gomez through the very heart of Spain. This chief penetrated from province to province, to the centre of Andalusia, laying the country under heavy contribution, and carrying off loads of booty from every place which he visited. The audacity of this enterprise seems for a time to have paralyzed the royalists. Consternation spread over Spain from Madrid to Gibraltar. Gomez attacked and carried several towns, and some bodies of troops who attempted to arrest his progress were totally destroyed. No less than three distinguished Spanish generals, each with a large army, were despatched to cut him off; but all their efforts to entrap him and his daring band proved fruitless. He was repeatedly surrounded, and apparently on the eve of being taken, but always succeeded in effecting his escape. At length, however, he was hemmed in to the sea-coast at San Roque, and his destruction seemed inevitable; but, by a daring and masterly movement, he broke through the line which encompassed him, and secured his retreat to the strongholds of the north.

Towards the close of 1836, the town of Bilboa was again invested by the Carlists, to whom it was an object of great importance, as being a city of sufficient consideration to give dignity to the court of Carlos, and an appearance of permanence to his establishment. It was, besides, the capital of Biscay, and inseparably connected, in the eyes of the Basques, with their *fueros* and local parliament. The siege was carried on with an ardour corresponding with the importance attached to the place. The defence was equally spirited and heroic. During the sixty days which the investment lasted, the fortitude of the besieged was put to the severest test, not only by the long-continued fire of the Carlists, by their repeated attacks, and by their mining operations, but by want of proper food and by sickness. At length General Espartero succeeded in compelling the Carlists to retire with the loss of all their guns and *matériel* for the siege, and Bilboa was relieved. The intelligence was received at Madrid with unbounded enthusiasm, and honours and rewards were heaped upon the defenders, and those who had so opportunely relieved them. The Chris-

History. tinos, however, as usual, neglected to follow up the success, allowing the Carlists to remain unmolested in the neighbourhood. Near St Sebastian they mustered very strong during the early part of 1837, and here they were attacked by the Anglo-Christinos under General Evans, and driven back with some loss; but receiving a great accession of strength, the Carlists in their turn compelled the royalists to retreat with at least equal loss. The affair of Hernani would have been much more disastrous, but for the steady bravery of a small body of British marines, who checked the advance of the Carlists, and retired to St Sebastian in good order. In a subsequent attack on Irun and Fuentarabia, General Evans was completely successful; but it seems perfectly clear that this officer was never cordially supported by the Spanish commanders. The defeat before Hernani would never have taken place had Espartero and Sarsfield supported him according to the concerted plan. The time for which the British legion volunteered its services expired in the month of May, and shortly afterwards it disbanded, nearly the whole returning to England in the most destitute condition. Meanwhile Don Carlos had followed the example of Gomez, by marching an army through the central parts of the kingdom. Our limits will not permit us to follow him in this daring but useless expedition. One body of Carlists advanced within a few leagues of Madrid, and all was consternation in the capital. But the Christino generals concentrating their forces, compelled the main body of the Carlist army to retire from the provinces into which it had made so fierce an irruption. Disunion also began to show itself in the camp of Don Carlos, so that, disappointed and disheartened, he retreated to his old fastness beyond the Ebro, accompanied however by a large convoy of booty. Besides these military operations, prosecuted on a large scale, there was a system of desultory warfare maintained all over the country, more destructive in its effects upon the inhabitants than the regular operations of an army. Brigandage, never viewed with much horror in Spain, had now become as common as a lawful trade. Remorseless cruelty characterized the proceedings of all parties; and civil life, except in the large towns, seemed for the time suspended.

The civil and parliamentary history of Spain for 1837 presents little that is of any importance. The new constitution formed a fruitful theme of discussion in the Cortes. After undergoing the alterations already mentioned, and some others of less moment, it was solemnly ratified by the queen-regent in the Cortes, and proclaimed to the nation. It is worthy of being noticed, that an attempt to introduce toleration in religious matters, by an amendment to the article which establishes the Catholic faith, met with the strongest opposition. This striking fact shows how deeply rooted the old Spanish bigotry remains in the national mind. During the year, bills were passed for the suppression of religious houses, and the abolition of the payment of tithes, the maintenance of the clergy being left to the government. Several judicious ecclesiastical reforms were projected; and among other important measures passed by the Cortes, was the abolition of the local parliaments in the Basque provinces. Ministerial changes repeatedly took place during the year, but into these we shall not enter.

The military operations of the Carlists in 1838 were less successful and less enterprising than they had been during the two previous years. Cabrera, indeed, a general who had frequently signalized his talents for war, had firmly established himself in Aragon and Valencia, and the bands of partisans allowed no respite to the distracted provinces; but we have to record none of those daring and brilliant flying expeditions which more than once traversed Spain in all directions with such celerity and success as to command the attention of Europe. Something of this kind was indeed attempted by Basilio Garcia, and by Tallada, but

History.

both these generals were signally defeated. The cause of Don Carlos was now visibly declining: the best and bravest of the chiefs who had served him had successively incurred his displeasure, and were either in disgrace, exile, or confinement; above all, the country was beginning to be favourably disposed to the queen. Her troops however were very unsuccessful in the field. General Orad was defeated at Morella, and General Alaix also suffered a repulse. But the principal battle fought between the Carlists and Christinos was that of Maella, where General Cabrera completely routed the queen's troops under Pardinás, but sullied his victory by butchering nearly two hundred prisoners in cold blood. The war throughout had been disgraced by similar atrocities, notwithstanding the efforts of Britain to put a stop to them. Both parties appear to have been equally guilty of this inhuman practice. The operations of Espartero were feeble and uncertain. He did little but march a large army from place to place, without striking a decisive blow. As usual, almost every part of Spain continued to be ravaged by guerilla bands, who swarmed over the provinces with no other objects in view but plunder and bloodshed. During the year, the Cortes had twice met; their deliberations chiefly referred to the state of the finances and the negociation of a loan, which was not effected. The ministry, always feeble, had now become more feeble than ever, notwithstanding that changes were continually taking place. The queen-regent found it impossible to form a strong government in the present political state of the country. Its helplessness was such that the generals commanding in the different provinces found it necessary to act independently of its arrangements, and to appropriate the revenues of each province to the payment of the military expenses incurred in it, instead of allowing the monies to pass into the treasury. Thus General Van Halen, who had organized a fine army of 40,000 men, called the army of the centre, after declaring the kingdoms of Aragon, Valencia, and Murcia, in a state of siege for the rest of the war, and that in future the civil were to consider themselves in subordination to the military authorities, proclaimed, that the entire revenues of those provinces should be paid into the military chest, and exclusively appropriated to the expenses of the war. This was probably the very wisest measure that could have been adopted for bringing the war to a speedy termination. Want of pay had repeatedly paralyzed the operations of the Christino armies; it had dispersed the British legion; and at this very moment it was exciting discontent, if not revolt, in the camp of Don Carlos. To place the pay of the queen's troops upon a sure footing, was therefore the first step to secure ultimate triumph in the field.

During 1839, the cause of Don Carlos rapidly declined, notwithstanding the desperate efforts made by Generals Cabrera and Maroto to maintain it. Espartero, the commander-in-chief of the queen's troops, after some hard fighting, cut off the Carlists completely from the plains of Alava, while Diego Leon likewise expelled them from the rich country between the mountains and the Ebro. Many towns and fortresses of importance, one after another, submitted to the triumphant Christinos, so that almost the only parts of Biscay which now owned the authority of Carlos were rugged mountainous tracts of country, whither no regular army could follow the fugitives. An armistice was at length concluded between Maroto and Espartero, which was followed by twenty-one Carlist battalions laying down their arms. Don Carlos himself, reduced to the last extremity, fled for refuge into France, where he formally renounced his pretensions to the throne of Spain, under certain conditions alike reasonable and necessary. The question relative to the fueros of the Basques and Navarre, which, it will be recollected, had been abolished, caused much uneasiness. It seemed perfectly evident that

these important provinces would not be satisfied, or completely surrender themselves to the queen's authority, unless their local privileges were restored. After some debating in the Cortes this measure was agreed to, government stipulating that it would so modify the fueros as to reconcile the interests of these provinces with those of the nation, and with the constitution of the monarchy. The only Carlist chief who gave any uneasiness to the government was Cabrera, who, little affected by the pacification of the northern provinces, still maintained his footing in Valencia, determined to support the cause of Carlos while an army remained to back him. Towards the close of the year, however, sickness paralyzed his exertions; nor is it supposed that he will be able to effect much when the season again arrives for an army taking the field. It is to be hoped that this protracted, bloody, and disgraceful war is now virtually at an end. It has left Spain overwhelmed with a debt which at present she has no prospect of being able to pay for many years to come. National property, chiefly that of the church, was sold to the amount of L.10,000,000, to meet the exigencies of the time, but even this large sum fell far short of what was required. The resources of the country are no doubt great, but a long period of peace, and a wise administration of public affairs, will be necessary before these are developed to their full extent. Spain has scarcely been free from internal war since this century commenced. The injury thus inflicted on agriculture, commerce, trade, and manufactures, is not to be estimated, while its effect on the morals of the people has been most pernicious, transforming the peaceful husbandman into a robber, and the aspiring student into a leader of banditti. That Spain has struggled through this sanguinary period of her history without being involved in total ruin, proves that the natural resources of the country are immense, and only require proper management to raise her above her former rank in the scale of nations.

STATISTICS.

The position and boundaries of Spain have already been described. Its extent north and south is from Tarifa Point, in the Straits, in 36° north latitude, to Cape Ortegal in Galicia, 43° 46', making 7° 46' of latitude, or about 540 English miles. From east to west the extreme points are Cape Creus, in Catalonia, 3° 17' of east longitude, and Cape La Roca, 9° 17' of west longitude, the distance in this direction being 560 miles. The Peninsula thus forms almost a square, allowance being made for the irregularity of its outline; and the entire extent of Portugal being excluded, it is reckoned to contain about 176,000 square miles English.

Spain may be considered as composed of a series of mountain terraces, which, projecting successively their rugged edges towards the south, present a flight of gigantic steps from the Pyrenees to the Mediterranean. The chains of mountains which terminate and divide the great plains of the Peninsula are branches of the immense ridge that, from the most elevated part of Tartary, runs across Asia and Europe, penetrates into the south of France by Switzerland, and, entering Spain in the direction of the valleys of Roncal and Bastan, separates Navarre from Guipuscoa, Biscay from Alava, the highlands of Burgos from the plains of Old Castille, and Asturias from the kingdom of Leon; then crosses Galicia, and dips into the ocean at Capes Ortegal and Finisterre.

The Pyrenees are lateral ramifications of this great trunk, which run east and west on the eastern side of Spain, and take a south-west and north-west direction on the confines of Aragon and Navarre. The accumulated mass of these mountains presents, towards the Peninsula, the convex side of a spherical segment, which, like a shield with its boss to

Statistics.

Statistics. the south, rounds its edges near the Atlantic and the Mediterranean, and rears the highest part of its curve on the Spanish territory, between the springs of the rivers Cinca and Ara. This eminence, called *Mont Perdu* by the French, is known, in Aragon, by the appellation of Tres Sorores, alluding to its three peaks, distinctly seen from Saragossa, of which the highest rises 4114 Spanish yards above the level of the sea. The line of perpetual congelation is there at the height of 2924 yards.

In the minor branches which strike off from the Pyrenees in a south direction, without forming a part of the great secondary chains, which we shall presently describe, there are some mountains too remarkable to be left unnoticed. Such are the Monsein, on the coast of Catalonia, near the town of Arens, and the well-known Monserrat, which rises, on the same coast, to the height of 1479 yards above the sea; such the Sierras of Ribagorza, Barbastro, Huesca, and Jaca, which take their names from the principal cities in their neighbourhood; such, finally, those numerous spurs of the great ridge which run into Navarre, whose various appellations would only tend to confuse the reader.

Of the main ridges which run across the Peninsula, that which rises to the west of the source of the Ebro was called *Idubeda* by the Romans, and formed the limits of the ancient *Celtiberia*. In its course towards the Mediterranean, the natives, according to a general custom, distinguish the various portions or great links of the chain by the appellation of *Sierras*, adding the name of some town or notable height in their vicinity. Such are the Sierra de Oca of Urbion (the *Distertia* of the middle ages), of Moncayo (*Mons Caunus*), of Molina, Albarracin, and Cuenza. Part of this chain forms the limits of Aragon and Castille; it then penetrates into Valencia, Murcia, and Granada, and ends in the Capes Oropesa (Tenebrium), Martin, Palos, and Gata. The small town of Alcolea, in the province of Soria, stands on this chain, at the height of 1486 yards above the sea. Its mean elevation, on the road between Molina and Teruel, in Aragon, is 1580 yards.

The first point where this great ridge splits into the minor chains, which lose themselves in the Mediterranean, is to the north of Albarracin, in Aragon. Of these branches the most remarkable is that which, entering the province of Valencia, is again subdivided into the smaller ridges which terminate at Peñiscola and Cape Oropesa. The waters that descend from these heights, to the north, mix finally with the Ebro, while the Turia and the Mijares are swelled by those which flow from the southern declivities. On the branch stretching towards Peñiscola, and in the limits of Aragon, rises the Muela de Ares, a conical mountain, deprived of its apex; whose top is an extensive plain covered with luxuriant pasture, and surrounded by fearful precipices, at the elevation of 1562 Spanish yards above the sea. This is one of the highest spots in the Peninsula. The Tagus, the Xucar, and the Cabriel, take their rise among these mountains, and divide the waters which flow from their sides between the Atlantic and the Mediterranean. Numerous flocks of sheep, both itinerant and stationary, find, in the valleys formed by this chain, the most abundant summer pastures.

From Albarracin, this chain strikes into the territory of Cuenza, in a direction nearly north and south. It then sends off a branch to the east-south-east, on which the Collado de la Plata, or Silver Hill, rises 1598 yards above the sea. It contains a quicksilver mine, which was formerly worked. From the neighbourhood of this town the Sierra de Espadan runs, like an unbroken bulwark, to the sea near Murviedro, in a direction between south-east and north-west. These hills are described as singularly grand and picturesque.

Near the source of the Tagus, the Iberian ridge sends off another branch, which, stretching in almost a southern

direction, separates La Mancha from the province of Murcia, to the west of the town of Albacete, and rises into the lofty mountains of Alcaraz and Segura (the ancient *Orospeda*), dividing the waters between the Guadalquivir and the Segura, the two main streams which severally and finally convey them to the ocean and the Mediterranean. One of the two great limbs which terminate the Iberian ridge runs into the sea at Cape Cervera; the other, bending to the south, skirts the kingdom of Granada, and disappears at Cape Gata. To the latter belongs the mountain called Cabezo de Maria, between Carthagená and Cape Gata, one league west of the town of Vera, on the coast of Valencia. It rises 2287 yards above the sea, and has its summit covered with snow during one half of the year.

Smaller branches of this chain project between the Turia and the Cabriel, which loses itself in the Xucar at Cofrentes. A ridge runs between the last-mentioned river and the Alcoy, another stream, which flows into the sea near Gandia. A minor chain separates the Alcoy and the mouth of the Segura. The province of Valencia is, in fact, divided by mountains into most fertile stripes, watered by numerous streams, and enjoying every blessing which nature grants to the most favoured climates.

The great ridge whose summits divide the waters between the Duero and the Tagus grows out of the Iberian chain, not far from the sources of the Xalon and the Tajuña, to the south of the city of Soria, and the site of the ancient Numantia. Where it divides the province of Guadalajara from that of Soria, it is called Sierra de Paredes, and Altos de Baraona. On one of the hills, north of Sigüenza, rises the Henares, which gives its name to the ancient *Complutum*, now Alcalá de Henares, the seat of a university. Near the source of the Lozoya, a rivulet which runs into the Xarama, these mountains are called Somosierra, till, more to the west, they bear the name of Guadarrama; an appellation which they preserve throughout the long course in which they skirt the provinces of Segovia, Avila, Guadalajara, and Madrid. The Puerto de Navacerrada, the highest point on the road from Madrid to the summer palace of San Ildefonso, is 2204 yards above the sea.

The mountains of Guadarrama are a very striking object when seen from the neighbourhood of Madrid, on the road to Old Castille. They principally consist of naked, fractured granite rocks, heaped up together, and adorned only towards their bases with single evergreen oaks, while the upper parts are bleak, dreary, and barren, presenting fantastic prominences, and in many places covered with perpetual snow. This chain, in its course towards Portugal, where it ends in the Rock of Lisbon, rises into some remarkable elevations. We shall notice that of Peñalara, between the sources of the Eresma and the Lozoya, 2834 yards above the sea; the Puerto del Pico, in the province of Salamanca; the Peña de Francia, and Sierra de Gata, on the northern limits of Spanish Estremadura.

The minor branches run nearly north and south from the main ridge, and may be traced from the opposite course of the rivers which flow either into the Duero and the Miño, or into the ocean, on the western coast of Galicia.

Almost parallel to the mountains of Guadarrama, we find the ridge which divides the waters between the Tagus and the Guadiana; but it rises to no great height, and is altogether of minor importance.

The third great branch of the Iberian ridge is the Sierra Morena (*Montes Mariani*), which divides the waters between the Guadiana and the Guadalquivir. It begins in the vicinity of Alcaraz, near the eastern limits of the province of La Mancha, issuing from that spur of the Iberian chain which terminates in Cape Palos, and, trending in a direction north-east and south-west, with La Mancha and Spanish Estremadura to the north, and Jaen, Cordoba, Seville, and Algarve in Portugal, to the south, ends in the

Statistics.

Great ridge between the Duero and the Tagus.

Chain of the Tagus and the Guadiana.

Ridge of the Guadiana and Guadalquivir.

Statistics. ocean at Cape St Vincent. The pass named Puerto del Rey, where the road from Madrid to Andalusia crosses these mountains, is 821 yards above the sea. Near Cordoba, where the bold skirts of the *Montes Mariani* are seen, within a short distance to the north, like a skreen raised to protect the rich and extensive plains watered by the Guadalquivir, the ridge borrows the name of the neighbouring city. On the southern limits of Estremadura, and to the north of Seville, it is called Sierra de Guadalcanal. The chain now bends to the south-west, forms the northern boundary of the Portuguese province of Algarve, and, through the Sierras of Caldeiraon and Monchique, connects itself with Cape St Vincent.

Ridge of Granada and Ronda. The brink of the last mountain plain towards the south of Spain is skirted by the ridge of Granada and Ronda, which, striking off at the extremity of the Iberian chain, is successively called Sierra de Gador, Sierra Nevada, Bermeja, and de Ronda, till it ends in various points of the coast, but most conspicuously in the Rock of Gibraltar.

Part of Sierra Nevada rises above the highest Pyrenees. The Cumbre de Mulhacen is 4254 yards above the sea, the Picacho de Veleta 4153. The line of perpetual congelation is found in these mountains at the height of 3305 yards.

Rivers. The five great streams which water the plains lying between the great mountain ridges, are the Miño, the Ebro, the Duero, the Tagus, the Guadiana, and the Guadalquivir.

The Miño. The Miño, or Minho (*Minus* or *Banis*), rises in Galicia, in the district of Lugo, from a beautiful spring called Fuente Miña. This river is navigable only to Salvatierra,

The Ebro. two leagues above Tuy. The Ebro rises, near Reynosa, out of a spring so copious that it turns a corn-mill a few steps from its source. After a course of 110 leagues, it flows into the Mediterranean at Alfaques. From the boundaries of Navarre to the sea, the Ebro makes a progress of $1^{\circ} 12' 42''$ towards the south. The chief towns on this stream are Logroño and Calahorra, in the province of Rioja; Tudela, in Navarre; Saragossa, in Aragon; and Tortosa, in Catalonia. It is a misfortune for Spain that this great river presents strong obstacles to navigation, both in its course and where it reaches the sea. Of the plans which have been conceived, and partly executed, to obviate these impediments, we shall presently have occasion

The Duero. to speak. The Duero, or Douro, has its source to the north of the city of Osma, in a deep lake, at the summit of that portion of the neighbouring chain of mountains called Sierras de Urbion. Its course is at first towards the south, passing by Garray and Soria, where it turns to the west, continuing in that direction till it reaches Miranda. From this town to Moncorvo the river falls again into a south direction. It lastly takes a decided course to the ocean, which it reaches near Oporto, having traversed a distance of 150 leagues. This river is navigable up to the tower of Moncorvo, a space of thirty leagues. The navigation, which was formerly obstructed by rapids, has been expedited through the exertions of the Portuguese company of Alto Douro. Some of the smaller streams flowing into the Duero rise at remarkable heights. The Adaja, which descends from the northern slope of the great chain between the Duero and the Tagus, is, at Avila, 1271 yards above the sea; the Eresma, when it flows by the castle of Segovia, is 1107 yards above the same level. We have mentioned that elevated part of the chain between the Tagus and the Guadiana which takes the name of Albarracin, and the truncated mountain called Muela de San Juan. An inconsiderable spring, denominated Pie Izquierdo, is the source of the majestic Tagus. In its course through the province of Cuenza it is considerably augmented by the contributions of several streams. Before its waters reach Aranjuez, they surmount the rocky edge of its native mountain,

and, dashing upon the plain beneath, sink into a pool of great depth, called Olla de Borlaque. The Tagus, now running placidly through the plains of Zorita and the royal gardens of Aranjuez, at the elevation of 621 yards above the sea, directs its course to Toledo, passes by Talavera, Alcantara, Abrantes, and Santarem, losing itself finally in the sea near Lisbon. The latitudes of several towns on the banks of the Tagus show the gradual inclination of its stream towards the south. The sources of the Guadiana are found north of Alcaraz, in La Mancha, at the pools of Ruidera. The course of the river is first to the north-west for eight leagues. It is then absorbed by the soil, and disappears for seven leagues. The first gathering of its waters, after their subterraneous dispersion, takes place near Daymiel. The spot is called Ojos (Eyes) de Guadiana. The stream now proceeds to Ciudad Real, the chief town of the province of La Mancha, to Merida, Badajos, Mertola in Portugal, and, re-entering the Spanish territory, terminates in the ocean at Ayamonte. In its course to this point, the Guadiana passes over a space of more than 100 leagues, but it is not navigable higher than Mertola in Portugal. The Guadalquivir occupies the centre of the plain which lies between the Sierra Morena and the chain of Granada, where it takes its course to the north-east of Jaen. The chief towns on its banks are Andujar, Cordoba, Seville, and San Lucar (*Templum Luciferi*). At the ferry near Mengibar, on the road from Madrid to Granada, the Guadalquivir is 203 yards above the sea. This river is navigable for large vessels up to Seville; but its bed being constantly raised and obstructed by growing shallows, the navigation is extremely tedious.

If we except the series of small lakes from which the river Guadiana takes its rise, there are in Spain few lakes that merit particular notice. The most remarkable of these is the lake of Abulfera, in the province of Valencia. This lake begins near the village of Cataroija, about a league north of the city of Valencia, and extends nearly four leagues, as far as Cullera. When it is full, it is about four leagues in length, and two in breadth; but it is so shallow that small boats can scarcely float in it. To supply the deficiency of water, an engine is employed, by which the neighbouring waters are drawn into the bed of the lake; and any superabundant water occasioned by heavy rains is carried off into these by means of an artificial opening. This lake contains a great many fish, and numerous aquatic birds make it their haunt.

According to Professor Hausmann, viewing Spain as a whole, a threefold principal difference is to be observed. The northern zone, which extends to the Ebro, differs entirely in its characters from the middle zone; and this again is completely different from the southern zone, which is bounded on the north by the Sierra Morena and a part of the Ostrandres. The northern zone, which includes Galicia, Asturias, the Basques, Navarre, the northern part of Aragon and Catalonia, is a widely extended, mountainous, and hilly country. The snow-fields and glaciers of the Pyrenees on the one side, and on the other the north and north-west winds, have a marked influence in lowering the temperature of the atmosphere, and in increasing the supply of water. The increased humidity is favourable to vegetation, which on the whole very much resembles that of the south of France; and the variety of rocks containing lime, clay, and sand, and also their frequent alternations, operate beneficially on the soil. Everywhere it invites to cultivation, and the inhabitants of this region are active husbandmen. The middle part of Spain, which comprises Old and New Castille, a part of Aragon, Leon, and Estremadura, is not so favourably circumstanced. Generally speaking, it is deficient in either beauty or variety of aspect. The broad and lofty table-lands present a uniform and monotonous surface, destitute of trees, and scorched by the rays

Statistics. of the sun. The corn-fields are wretchedly cultivated, and desert heaths of cistus everywhere meet the eye. Plantations of olive-trees are rare; here, in short, every kind of vegetation dwindles for want of water. In most cases the rivers carry but little water in comparison with the extent of the land and the number of considerable mountain chains. The causes of this great deficiency are principally the extreme dryness of the atmosphere; the inconsiderable cover of snow on the mountains, and its short continuance; the absence of forests and great moors on the heights; and the comparatively inconsiderable breadth of the mountain ranges. The southern and south-western part of Spain, which comprehends Andalusia, Granada, and Murcia, is very different from that just described. On the opposite side of the Sierra Morena the whole land has a more southern aspect, which announces itself not only by the vegetable, but likewise by the animal kingdom. The great difference of climate is produced by the southern situation, the exposure of the acclivity on the south and south-west to the African winds, and the strong reflection of the solar rays from the lofty naked mountain-walls. The mountain ranges are more closely aggregated, the valleys more deeply cut; and there is also a greater difference in the rocks and in their position, so that extensive table-lands cannot be formed. The south of Spain thus possesses not only a much higher temperature, one fit for the orange and the palm, but also a more varied and more favourable soil for cultivation. In East Valencia and Murcia, in the south of Andalusia and the Algarves, in Western Alemtejo and South Estremadura, the rich and varied vegetation rivals that of the fertile plains of Syria. In Andalusia frosts are unknown, and the snow, if it ever falls, melts the moment it touches the soil; so that it is not surprising that, in the cultivated districts, the Spaniards, so famous for their maritime expeditions of yore, should have introduced many vegetables from remote parts of the world, thus giving a perfectly tropical appearance to the country. There is, however, a deficiency of moisture, but it seems only to affect the growth of some of the lower species of plants.

Productions.

Passing over such productions of the soil as are only interesting to the botanist, we shall enumerate those which come under the cognizance of the husbandman. Spain may be reckoned one of the most fruitful countries of Europe, and it presents a great variety of products. Wheat, secale, barley, maize, and flax, are cultivated in almost all the provinces, but still not in crops sufficient for home consumption. Oats are neglected, barley being given to the cattle instead of that grain. Oil and soda are the principal products of the southern shores of the Mediterranean; the others are sumach, and different esculent plants of an admirable quality. In the same part of the country are fields of saffron, plantations of rice, which stretch out like so many plains, and the cotton shrub thrives as on its native soil. The mulberry trees are very luxuriant, and their leaves afford rich nourishment to the bombyx, which easily accounts for the superior quality of the silk. In the south of Spain there is an immense variety of the most delicious fruits, not only such as are common in temperate climates, but many which naturally belong to the tropical regions. The sugarcane grows near the cotton plant, and numerous olives furnish the oil which forms so important a branch of commerce. Kali, from which barilla is extracted, is produced in great abundance in Valencia; anise, maize, and different dye-stuffs in Murcia; and the honey of Cuenza is still as celebrated as it was in the time of the Romans. Among the vegetable products we may briefly mention chestnuts and a variety of other nuts, the cork-tree, palm, lemon, banana, date, pomegranate, fig, citron, cheremoya, laurel, bay, cypress, almond, and strawberry tree; potatoe and other culinary vegetables; forests of oak, pine, and other trees, chiefly in Catalonia, the Asturias, Galicia, and the Sierra Morena.

Statistics. Extensive valleys covered with rich pastures are found in Navarre, and numerous herds are fattened on them. In the Asturias considerable forests still exist, chiefly of evergreen oaks, from which naval timber is obtained. But of all the vegetable productions of Spain, the vine is the most important, the lands being almost everywhere favourable to its culture. The excess of the vintage above the quantity consumed in the country forms a considerable branch of the export trade, and it is capable of being greatly extended. The best wines are those of Peralta in Navarre; Ribadavia and Betanzos in Galicia; Mansanares and Val de Penas in La Mancha; Xeres or Sherry, San Lucar, and Rota, in Seville; Cabra, Lucena, and Campine, in Cordova; Malaga in Granada; and lastly, Alicante in Valencia. Sherry wine is produced in great quantities in the plain of Xeres, and a considerable portion is exported to this country. Mr Jacob estimates the quantity of this wine annually produced at 40,000 pipes, of which 15,000 are exported, mostly to England. The finest wine is produced in Malaga, but not in large quantities.

Mr Swainson thus describes the zoology. "The native zoology has been so little investigated, that nothing beyond a meagre list could be furnished of indigenous animals. In the mountains of Asturias the ibex is not uncommon, and the Alpine squirrel (*Sciurus Alpinus*) is only found in the Pyrenees. In the southern parts, bordering on the African shore, a few species of warblers have recently been found, which are as yet unknown to the rest of Europe. The European bee-eater frequents the vicinity of Gibraltar in large flocks during the season of migration. Among the domesticated animals, the horse and sheep deserve particular notice, as having been long celebrated throughout Europe. The best horses are generally about four feet six or eight inches in height; they have all the fire, docility, grace, and action of the beautiful Arabians of Barbary, and there can be no doubt of these noble animals having been introduced by the Moors and crossed with the native breed. Those of Andalusia, Granada, and Estremadura, are the most distinguished. At Zeres are found two perfectly distinct races; the one, which possesses the fine qualities above mentioned, is still preserved in all its purity at Chartreux. The other race is larger, stronger, less elegant, and used for common purposes. But little care has latterly been bestowed in keeping up the more noble breed, so that fine horses are not so common in Spain as formerly. The mule in so mountainous a country is particularly useful, and, with the ass, is principally used for conveying goods into the interior. The breeds of the latter are very fine, and are hardly excelled by those of Egypt. Spain is still celebrated for its Merino race of sheep. The flocks are kept constantly travelling during the greater part of the summer, but are carefully pent up in winter. This race, subdivided into breeds, is extended over the greater part of Spain, but those of Cavage and Negrate are the best. A third breed, the Sowen, appears more hardy, and passes the winter in Estremadura, Andalusia, and New Castille. These three constitute what is called the Transhumante, or travelling race, to distinguish them from the Estautes, or those of a somewhat inferior breed, which do not migrate. The best fleeces are those which appear almost black on their surface, caused by the dust adhering to the peculiar greasy pile; for it is invariably found that such fleeces are of the purest white beneath." There is a very large breed of oxen in the country round Salamanca; but the cattle of Spain have been much neglected, the mountaineers deriving all their milk and butter from goats. Fine cattle, however, are reared in the Asturias; and pigs are very common on the mountains of the same province. The wild boar, the wolf, the bear, and different kinds of deer, are still found in Spain, but these are gradually becoming extinct. The chamois and the lynx still find shelter in the Pyrenees and

Statistics. the mountains of Cuenza. The wild animals of the southern part of Spain are very similar to those of the north of Africa.

Minerals. Spain has long been celebrated for its richness in minerals, and large veins of various metals are still found in several parts of the country. Gold and silver mines were formerly worked; but they have been given up, although grains of these metals are still found. Lead is found in considerable quantities; the principal veins, as the lead-glance veins of Sinares, are found in granite. The colossal deposit of galena, which yielded 600,000 quintals of lead in 1829, lies in irregular masses in a limestone formation. The principal mines are near Tortosa in Catalonia; at Zoma, Benasques, and Plan in Aragon; in Estremadura, in Murcia, in Old Castille, in Seville; and at the district of Linares, in Jaen. Mercury is also found, and at Almaden there is a rich mine of this valuable mineral, which is wrought in the clay slate. Iron ore occurs in very large quantities, principally in the northern provinces. In the Pays Basque, the lias formation is very rich in iron ore; and at Solomostro, near Bilboa, enormous deposits of carbonated iron are found. Veins of copper, antimony, and sulphur, are occasionally discovered, but not in such quantities as to be worth working. Coal also exists in considerable quantities in many provinces; and this mineral is gaining in importance every year, from other fuel becoming scarce.

Agriculture. Although Spain possesses all the advantages of climate, and the soil is generally fertile, the agriculture of the country is in a state of deplorable backwardness. A variety of causes has been assigned for this, but the principal cause is what has been appropriately termed the curse of the Mesta. This is a privilege granted to the proprietors of flocks to conduct their sheep into different provinces for the sake of pasturage. In their progress the sheep commit considerable depredations on the crops. The law of entail, which exists in Spain in its worst form, is also supposed to hinder improvement in agriculture; but perhaps the most serious obstacle to improvement is the want of internal communication, and the indolence of the rural population. The farms are generally small, and the farmers of a district live together in villages. There is no rotation of crops, and the wheat, after a slight ploughing, is sown at the commencement of the rains. The operation of thrashing and cleaning the grain is performed in the open air, and the grain is left in the fields or concealed in caves till sold. Implements of husbandry are of the rudest description; fanners are unknown except about the sea-coast, and the spade is still in use in some of the mountainous parts of the country. The most careful cultivation is to be found in the *huertas* of Granada, Murcia, and Valencia, which are well irrigated by the waters of the Xenil, Segura, and Xucar. Rice is produced in Valencia, and a mild red pepper is the chief vegetable cultivated in Murcia. These three provinces are considered as the gardens of Spain, and annually yield three and four crops of vegetables, maize, and a mild red pepper. In spite of this fertility, however, it is calculated that the entire lands of Spain do not yield more than from one and a half to two per cent. to the proprietors. Some improvements have recently been introduced, but even now scarcely a fourth of the surface of the country is applied to any profitable use. A far greater extent of land is devoted to pasturage than is required for the maintenance of the cattle; and only about a twelfth of the superficies is occupied by wood. In Biscay, agriculture has made many improvements; and in spite of the disadvantages of soil, the population of this district is more numerous, and grain cheaper, than in the fertile plains to the south and east of Seville; which, if properly cultivated, might supply all Spain. "The kingdoms of Old Castille and Leon," says a writer in the Foreign Quarterly Review, vol. v. "are justly considered the granaries of Spain. They have their outlets in

the north by various ports from Gijon to St Sebastian, the principal being Santander and Bilboa. The provinces of Burgos and Palencia are the nearest points from which these ports get any considerable supply; the distance being from 130 to 140 English miles from each. The elevated and rich *campos* which extend from Logroño to Burgos, and thence on each side of the Arlanza and Pisuergra, and along the Cauvion, and numerous other streams which water the provinces of Palencia, Valladolid, and Zamora, yield immense quantities of wheat; and further to the west, and on the south side of the Douro, the provinces of Toro and Salamanca may be considered as forming a portion of the richest wheat country in Spain, or perhaps in the world. The crop is often so abundant for a series of years, that the produce of the fields at a distance from the villages is sometimes allowed to rot on the ground, the expense of conveying it home being considered beyond its value. It was calculated that the accumulated surplus of four or five successive years, in the *silos* and granaries of these plains, amounted at the close of the harvest of 1828 to 6,000,000 of fanegas, or 1,200,000 Winchester quarters. The ordinary cost of carriage does not exceed seven or eight shillings for every hundred miles; but the means of transport are so defective and so badly organized, that when any extraordinary demand for exportation takes place, the rates advance accordingly. Thus, in September 1828, the usual price was seven or eight shillings; but in consequence of extensive demands from France and England, it rose two months after to fourteen shillings and sixteen shillings per quarter. The grain of Spain is of the finest quality, that of Andalusia bearing a price ten or fifteen per cent. higher than that of any foreign grain brought to the markets of Cadiz. In spite of her facilities for agriculture, it is remarkable that Spain regularly imports, upon an average, 400,000 quarters of grain. This may arise from the want of proper means of transporting grain from one province to another, and not from any deficiency in the produce of the country." Several of the provinces, such as Galicia, Asturias, part of Leon, Santander, Biscay, and the kingdom of Navarre, barely produce sufficient for the consumption of their inhabitants. Catalonia does little more than maintain the half of its inhabitants; Valencia exports rice, but both it and Murcia import wheat; Cuenza, Guadalaxara, Segovia, Avila, and Madrid, produce less than their consumption. The provinces of Old Castille, part of Leon, Estremadura, part of Andalusia and Toledo, produce such an abundance that they might supply all the deficiencies of the other parts of Spain, and also export to foreign countries in seasons of plenty. Miñano calculates the gross amount of agricultural produce in 1826 at L.76,965,000, and the net produce at L.28,403,666. The same authority estimates the number of cattle, &c. in the kingdom in 1826 as follows: horned beasts, 2,944,885; horses, 400,495; mules, 223,646; sheep, 18,687,159; goats, 5,187,668; asses, 641,788; swine, 2,728,283; bee-hives, 1,697,593.

The manufactures of Spain are in a very depressed state, although some thriving manufactories exist, principally on the sea-coast. The manufacture of silk was formerly the grand staple of trade, and although now much depreciated, it is calculated to furnish employment for nearly 16,000 persons. Numerous manufactures of various kinds have been established in Catalonia within the last twenty years; those of silk and cotton are the most extensive, and are in a thriving state. The looms of Valencia are calculated to employ at the present day nearly 3000 persons, and produce tissues, gauzes, and ribbands, equal to the French manufactories. The silk manufacture of Talavera de la Reyna and Saragossa are still in high repute. The latter province also produces cloth, which is much in request. Galicia annually imports 20,000 hundredweight of flax, which is conveyed to Santiago, and distributed throughout

Statistics. the villages of this province to be converted into linen, and sold in the Castilles. In the north, Bilboa and Santander, in the south, Seville and Cadiz, are the great entrepôts for the exportation of wool, which is also spun and manufactured into cloth in Catalonia and Barcelona. These manufactures, however, are by no means sufficient for the inhabitants, and almost every species of manufacture is imported. In Catalonia there are numerous manufactories of coarse cloth, which enjoy a monopoly; coarse cloths of foreign manufacture being almost prohibited by a heavy tax. The finest cloth is manufactured in Valencia, and the trade is in a flourishing state, employing nearly 10,000 hands. Tanning is the most active branch of manufacture in the northern provinces. Potteries are numerous, but the articles produced are generally of an inferior description. There is a royal porcelain manufactory at Madrid, the produce of which is very superior, but it costs the government more than it returns. Hat and paper manufactories have also been established, and have met with considerable success. The manufacture of arms forms a part of the trade of Spain, but the quantity made is by no means great. There are two large factories in Biscay; at Abaceti and Toledo swords are made; at Segovia, fire-arms; and at this latter place, as well as at Seville and Placencia, there are good foundries. Seville carries on a considerable trade in leather, a species of which, prepared with gall-nuts, is in much request. Ferrol and Vittoria possess considerable tanneries; and the former has an establishment where varnished leather is made. Iron manufactories are very numerous in Biscay, but none of them is conducted on an extensive scale. In almost every village in this province some kind of iron ware is manufactured; horse-shoes, fusils, locks, and bedsteads being the chief articles, which are sent to the interior. Cast iron utensils are prohibited from being imported into Spain; but this regulation does not seem to be attended with any great advantage, for there is only one smelting manufactory at Bilboa. Several other iron manufactories have been established throughout the country, the principal being at Pederoza and Martulla in Andalusia; but it does not appear that they have met with any degree of success. Iron ore is prohibited from being exported, but considerable quantities are nevertheless sent to France. Manufactures are much checked in Spain by the system of monopoly, several of the largest manufactories being in the hands of the government, and consequently ill conducted.

Commerce. The commerce consists chiefly in the exporting of wines, wool, brandy, fruits, silk raw and manufactured, lead, iron, mercury, barilla, and a few other articles, amounting in all, according to a government return in 1826, to the value of L.1,584,000. Iron, in bars, is exported in considerable quantities from Bilboa, Cumana, and Vittoria, chiefly to Bayonne and Bordeaux. Malaga and Alicante wines are also important branches of commerce; and the coarse wines of Murviedro are extensively exported. The export of dried fruits gives activity to the ports of Alicante, Malaga, Seville, and Valencia; and the latter town is famous for its dyes. The imports of Spain consist of sugar, salt fish, spices, wood, rice, butter, cheese, hides, wool, and cotton, and almost every manufactured article. The transport of salt from Cadiz and Torrevieja, for the fisheries of Galicia, is an important branch of commerce, and, along with the fisheries themselves, employs a great number of hands, producing the best sailors, and giving activity to the towns and villages on the coast, which is seldom seen in the interior. The net produce of commerce and manufactures was estimated by Miñano in 1826 at L.14,660,000. It is difficult to arrive at any correct estimate of the value of the exports and imports of Spain, from the want of official documents; and even when these are obtained, little reliance can be placed on them. The following is from an official document published in 1826.

Value of the Imports and Exports in 1826, distinguishing the Countries.

	Exports.	Imports.
Africa.....	L.340	L.11,090
Asia.....	...	214,660
United States.....	45,925	68,940
England.....	637,800	957,395
France.....	450,350	726,170
Germany.....	26,670	150,510
Holland.....	56,185	133,525
Prussia.....	5	2,060
Russia.....	4,085	135,800
Denmark.....	11,585	30,070
Sweden.....	6,210	87,080
Turkey.....	55	31,255
Switzerland.....	...	8,930
Sardinia.....	2	110,895
Italy.....	83,740	146,300
Portugal.....	146,160	204,090
Spanish American Colonies.....	330,373	754,690
Total.....	1,799,485	3,773,475
Amount of importations from the different states of Europe, the United States, Asia, and Africa.....	L.3,018,785	
Importations from Spanish Colonies.....		754,690
		L.3,773,475
Amount of exportations to states in Europe, America, Asia, and Africa.....	L.1,469,112	
Exportations to Spanish Colonies.....		330,373
		L.1,799,485

This table shows a balance of L.1,973,990 against Spain, of the imports over the exports; and the important article of tobacco is entirely omitted; neither is there any account of the imports and exports to and from the free provinces of the north.

Banking is almost unknown in Spain, the principal merchants doing the business of bankers. There are no substitutes for cash in ordinary transactions, bills of exchange being principally used; but these do not pass from hand to hand as cash, except by special arrangement. The difficulty of transmitting specie is the cause of these bills being much used; merchants preferring rather to pay a premium than run the risk of losing the specie altogether. The rate of exchange of course varies with the supply of bills in the market, and also with the character of the houses offering the paper. Most of the bills are at short dates, generally within one month. Some are as short as two days; and these are allowed eight days' grace, unless the word *fixed* is written on them. Interest generally varies from three to four and a half per cent. on discounting bills, but this mode of negociation is not much practised. Interest on mercantile transactions is understood to be fixed at six per cent., and three per cent. on mortgages; but the law is easily evaded, there being no penalty inflicted on those who charge more than the legal interest. There are no bankers with whom money can be lodged; and it is customary for people rather to horde up their money than to run the risk of its being lost in the hands of merchants.

In internal communication, Spain lies under great disadvantages, both from the mountainous nature of the country, and the obstructed navigation of the rivers. In the hands of an enterprising people, these difficulties might soon be overcome. The roads and canals are not numerous, and, if we except the principal highways, are but imperfectly kept. The two roads which run from Madrid to Burgos, the one through Valladolid, and the other through Aranda de Douro, are kept in good condition; but the great eastern roads are

Statistics. represented as in a wretched state. The road to France by way of Vittoria and Irun is kept in excellent condition, considering the mountainous nature of the country through which it runs. The road to Corunna and Ferrol, through Galicia, is in many places impassable for carriages or carts. That over the Sierra Morena to Seville is well kept. The roads of Catalonia are said to be in better condition than most in Spain. These roads are kept up partly by tolls, and partly by local taxes; but the amount collected is not sufficient for maintaining proper communications. It appears that L.92,400 were expended in repairing and making roads and building bridges in the year 1826, and L.89,240 for the same purpose in 1827. The ordinary mode of conveying goods is by means of mules, asses, or small carts drawn by oxen. Stage-coaches are becoming more common; but these can only be used on the great roads, the ordinary cross roads being generally too bad for such conveyance. In Biscay and Navarre the roads are under the superintendence of the provincial administration, and are more numerous, better constructed, and more carefully managed, than any others in the country.

The canals are stated to be in a much more deplorable condition than the roads, and although many have been projected by government, none of any importance has been completed.

Statistics. The most important is that which was intended to unite the Mediterranean Sea with the Bay of Biscay; but of this mighty undertaking only two portions exist, the canal of Aragon, running parallel to the Ebro, from Saragossa, and that of Old Castille, along the Pisuerga and Carrion, by Placencia. Neither of these portions, however, approaches the sea, and their benefit is therefore limited. The other canals are, that of Castille, which connects the port of Santander with the Duero; the canal of Segovia, which connects that town with the river of the same name; and the canal of San Carlo, which is constructed to give a port to Fortoza.

Population. The population of Spain presents fluctuations which can only be accounted for by the fact of the internal wars which have so frequently convulsed her, or on the supposition that the returns which have been published are incorrect. It has been gradually increasing for the last two centuries, and latterly at a more rapid progression. It appears that in 1700 the population was estimated at 8,000,000. The following table, extracted from M'Gregor's Statistics of Nations, gives the population in 1803 as exhibited by the official tables, and in 1827 as given by Moreau de Jonnes in his Statistics, which latter, however, must have exceeded the real numbers, as the population was ascertained in 1837 to amount only to 12,168,572.

General Description.	Provinces.	Superficies.		Population.		Inhabitants to Square Mile.	Capitals.	Geographical Position of Chief Towns.		Population 1827.
		English Miles.	French Leagues.	1803. (a)	1827. (b)			N. Lat.	E. Lon.	
New Castille	Madrid.....	1,330	110	228,520	297,812	224	Madrid.....	40 25	3 33	201,000
	Toledo.....	8,863	734	370,641	485,203	54	Toledo.....	39 52	4 11	15,600
	Guadalaxara...	1,970	163	121,115	157,338	79	Guadalaxara...	40 33	3 22	7,000
	Cuenza.....	11,410	945	294,290	382,577	33	Cuenza.....	40 6	2 16	7,000
Old Castille	La Mancha.....	7,620	631	205,548	257,210	33	Ciudad Real....	39 0	4 3	10,000
	Burgos.....	7,752	642	470,588	611,762	78	Burgos.....	42 25	3 55	12,000
	Soria.....	4,118	341	198,107	267,537	65	Soria.....	41 42	2 30	5,000
	Segovia.....	3,502	290	164,007	221,379	63	Segovia.....	41 6	4 10	12,000
Leon.....	Avila.....	2,600	215	118,061	153,479	59	Avila.....	40 45	4 45	4,000
	Leon.....	5,943	493	239,812	311,755	52	Leon.....	42 45	5 27	5,000
	Palencia.....	1,751	145	118,064	153,482	87	Palencia.....	42 6	4 35	10,000
	Toro.....	1,992	165	97,370	126,581	63	Toro.....	41 45	5 37	9,000
Leon.....	Valladolid....	3,272	271	187,390	243,607	74	Valladolid....	41 45	4 35	32,000
	Zamora.....	1,606	133	71,401	92,821	57	Zamora.....	41 35	5 45	7,000
	Salamanca....	5,128	471	209,988	272,982	53	Salamanca....	41 21	5 40	14,000
	Asturias.....	3,725	308	364,238	464,565	124	Oviedo.....	43 24	5 55	10,000
Galicia.....	Galicia.....	16,060	1330	1,142,630	1,585,419	98	Santiago.....	43 24	8 20	28,000
Estremadura...	Estremadura..	14,478	1199	428,493	556,780	38	Badajos.....	38 49	6 47	12,000
Andalusia....	Seville.....	9,080	752	746,221	970,087	106	{ Seville..... }	37 24	5 39	91,000
	Cordova.....	4,202	348	252,028	327,256	77	{ Cadiz..... }	...	...	70,000
	Jaen.....	3,236	268	206,807	276,905	85	Cordova.....	37 52	4 46	46,000
	Granada.....	9,720	805	692,924	1,097,093	112	Jaen.....	37 48	3 51	18,000
Murcia.....	Sierra Morena	1,304	108	6,196	...	...	Granada.....	37 16	3 46	80,000
	Murcia.....	7,957	659	383,226	493,192	61	Carolina.....	38 30	3 5	...
	Aragon.....	14,882	1232	657,376	856,219	57	Murcia.....	37 59	1 5	35,000
	Valencia.....	7,764	643	825,059	1,255,095	161	Saragossa.....	41 38	1 2	55,000
Catalonia.....	Catalonia.....	12,111	1007	858,818	1,116,461	92	Valencia.....	39 29	0 23	66,000
Navarre.....	Navarré.....	2,475	205	221,728	288,244	116	Barcelona.....	41 22	2 10	120,000
Biscay.....	Biscay.....	1,280	106	111,436	144,875	113	Pampeluna.....	42 46	1 42	15,000
	Guipuscoa....	628	52	104,491	135,838	216	Bilboa.....	43 14	2 42	15,000
	Alava.....	1,093	90	67,523	92,807	84	St Sebastian...	43 10	1 58	9,000
	Majorca and } Cabrera..... }	1,352	112	140,699	...	...	Vittoria.....	42 55	2 55	7,000
Balearic Isles	Minorca.....	242	20	30,990	242,893	136	Palma.....	39 30	2 25	30,000
	Iviça and } Formen..... }	181	15	15,290	...	...	Ciudadella.....	40 5	3 15	...
	Total.....	176,627	1555	10,351,075	13,953,959	78	Iviça.....	38 53	1 29	...

(a) Official census. (b) As given by M. Moreau de Jonnes, in his Statistics for 1834. It is generally believed that the census of 1803 is much below the actual number of inhabitants; and according to the returns of 1723 it would appear that in 103 years the population had increased from 7,925,000 to nearly 14,000,000. It also appears, from the observation of most persons, that the actual population of Spain had increased more slowly than that of any other country, particularly before losing her South American empire. M. Moreau de Jonnes estimates the population in 1834 at 14,660,000. According, however, to a return of the number of senators and deputies to the Cortes from all Spain, corresponding to the population of the provinces, which appeared in the royal decree of 3 August 1837, the exact population of the kingdom was 12,168,572.

Statistics. THE OFFICIAL RETURNS OF THE POPULATION FOR 1826.

Householders having the Qualification of Electors.

Nobility, including men, women, and children...	1,440,000
Citizens and farmers, &c.....	1,560,000

Heads of Families, viz.

Magistrates and advocates.....	5,883
Notaries.....	9,683
Attorneys and clerks of law-courts.....	13,274
Medical men.....	17,990
Public functionaries and clerks.....	27,243
Merchants.....	6,824
Agricultural proprietors.....	364,514

Heads of families.....	445,411
Women and children.....	1,128,275

1,573,686

Agricultural Population.

Agricultural proprietors.....	364,514
Farmers.....	527,423
Labourers.....	805,235
Proprietors of flocks and herds.....	25,530
Shepherds.....	113,628

Heads of families and others.....	1,836,330
Women and children.....	6,777,140

Total agricultural population.....	8,613,470
------------------------------------	-----------

Merchants and Manufacturers.

Merchants.....	6,824
Retail dealers.....	18,851
Manufacturers and labourers.....	489,493

Heads of families.....	515,168
Women and children.....	1,803,088

Total manufacturing population.....	2,318,256
-------------------------------------	-----------

Other Classes.

Domestics (one in thirty-seven inhabitants).....	276,000
Vagabonds (one in seventy).....	140,000
Smugglers (one in a hundred).....	100,000
Custom-house officers.....	40,000
Officers of the Inquisition.....	22,000
Wandering beggars.....	36,000
Convicts.....	2,000

All other classes, or one in thirteen inhabitants.....	700,000
--	---------

Extent and Population of the Colonies of Spain in 1827.

	Square Miles.	Inhabitants.
Philippine Islands.....	...	2,525,000
Canary Islands.....	7,451	210,000
Cuba	46,700	704,487
Porto Rico }		284,957
Presidencies of Africa.....	36	4,000
Total inhabitants...	...	3,528,444

The population of Spain, according to the royal decree of August 1837, being 12,168,572, if we add the 3,528,444 of the colonies, the entire population of Spain and its dependencies will be 15,697,016.

The Roman Catholic religion exclusively prevails in Spain, and here in all ages it has assumed its most bigoted VOL. XX.

and intolerant form. The church establishment includes eight archbishops and seventy-two bishops, 2393 canons, and 1869 prebendaries, together with an immense multitude of other ecclesiastics, under various denominations. In the year 1835 there still remained 1940 cloisters, containing 30,906 monks. Of these the Franciscans alone possessed 651 cloisters, with 11,232 monks and lay-brothers. But by a royal decree of the above year, all the religious houses which did not contain more than twelve monks were abolished. The number of monasteries thus condemned amounted to 900. Their revenues were applied to the extinction of the national debt. The whole income of the church is valued at L.12,500,000 sterling, and the portion of the income which is consumed by the spirituality exceeds the collective income of the state by about L.2,000,000.

Education.

The institutions for public instruction in Spain are the universities of

Valencia, established in 1411	Students in 1827.....	1569
Valladolid.....	1346	1247
Saragossa.....	1474	1175
Santiago.....	1532	1054
Seville.....	1504	807
Granada.....	1531	812
Cervera.....	1717	573
Huesca.....	1354	537
Oviedo.....	1580	420
Salamanca.....	1404	418
Alcala.....	1490	364
Onate.....		270
Toledo.....		257
Palma.....		177
Orihuela.....		124

There are two artillery schools, and a hundred and sixty-three colleges and seminaries of a higher order, containing 3810 pupils. The common schools throughout the country have been estimated at about 20,000.

There are numerous public libraries in the more important towns, some of them of considerable extent. One at Madrid contains about 130,000 volumes, numerous manuscripts, and a rich collection of medals. The prohibition, however, of many standard works greatly limits their value.

Finances.

According to the budget of 11th February 1837, the expenditure amounted to.....1,929,300,795 reals. The income to.....800,000,000 ditto.

With regard to the national debt of Spain it is impossible to obtain any thing like a correct estimate. For the last eight or nine years it has continued to accumulate with fearful rapidity, and loan after loan has been negotiated. It seems almost impossible that so large an amount as from two millions to two millions and a half sterling, can be annually collected to pay the interest of the national debt in a country already grievously oppressed with taxes, and where trade is in some measure stagnant. The balance of her trade, ever since the loss of her colonies, has been in the ratio of two to one against Spain, while the whole value of her exportable produce, even in the most prosperous periods, has not exceeded three millions and a half; and this is now supposed to be greatly reduced, since the exports to England, which is the greatest consumer of her fruits, wine, and wool, have barely averaged for the last four or five years one million sterling. In 1833, the public debts amounted to L.165,000,000, and as the expenditure exceeded the income, and various loans have since been negotiated, it has now materially increased. Taxation in Spain is very heavy, and is levied with little regard to the well-

Statistics. being or comfort of the population. It is grossly unequal and arbitrary, no one ever being able to tell what he may be required to pay; and the greatest abuses exist in its collection. Scarcely one half of the tax laid on the inhabitants ever reaches the government, the rest being absorbed by the various officers employed. No fewer than 16,000 persons are employed in collecting the custom-duties; and being ill paid, they are open to bribery, and even levy contributions for their own pockets. The same duties are not imposed in the different towns, one merchant being called upon sometimes to pay L.40 of a tax, while another in a different place may have only to pay L.20. The *alcabala* is a tax which is levied upon every article of use, and presses with great severity upon the poor. It was formerly an impost on the transfer of commodities from one hand to another, but is now paid by gate-duties. In towns which are not walled or have no gates, this tax is levied by a calculation of the amount paid by another town of the same size. Tithes are, next to the *alcabala*, the most oppressive of the taxes; but the clergy do not receive perhaps one half of the amount collected. There is also a tax of six per cent. on the produce of all rented lands; and on the accession of the heir to an entailed estate, the first half year's rental falls to the government. A tax of L.100,000 is levied yearly upon the merchants: the finance minister fixes the amount which each intendency has to pay, and the intendant the proportion which each town must pay; and another magistrate assesses the individuals. The revenue from tobacco and salt is considerable, they being monopolies in the hands of government. The amount of salt which each town ought to consume is fixed; and landowners and farmers pay in proportion to the number of their dependents, and the cattle and sheep which they possess. The clergy pay an annual subsidy, in addition to some other contributions.

The state of crime shows Spain to be in a very imperfect state of civilization. The administration of justice is extremely slow and uncertain, and indeed all the legislation upon criminal affairs is as bad as possible. The crimes most complained of are those of assassination and robbery; and although these do not prevail now to the extent they once did, the returns show that murder is still a very common crime. The returns for the year 1827 give the number of murders as 1223, and attempts at murder as 1773; and this report is very inaccurate, as no returns were sent from either Aragon or Valencia. A person robbed or assaulted is bound over to prosecute; and should he fail to prove the guilt of the criminal, he has to pay all expenses of the suit. Witnesses are liable to imprisonment in case of the prisoner being acquitted; and this preposterous law has a strong and obvious tendency to interrupt the course of justice.

The poor in Spain are numerous, and begging is considered as no disgrace in many of the provinces. Even students have been known to go on begging excursions during the vacation, labour being in their estimation a greater disgrace than asking alms. There are numerous hospitals in the large towns, chiefly under the management of the clergy. The funds for maintaining them are principally derived from legacies of lands and rents, partly bequeathed by private individuals, and partly by bishops. In the northern provinces the hospitals are supported chiefly by public subscriptions and collections in the churches, the legacies being unimportant. The convents and monasteries support many paupers; the Franciscan, Dominican, and Capuchin orders, although beggars themselves, keeping open table for a certain number of poor. A contribution of L.30,000 is annually made from the public funds, being a portion of the revenue collected by the vicar-general of the *cruzado*. Notwithstanding these institutions, however, the number of beggars is still very great. Only in some of the towns is begging prohibited, and in these

the vagrants are employed much in the same way as in our own workhouses. Statistics.

The character of the Spaniard is grave, adventurous, romantic, honourable, and generous. He is not inclined to adopt foreign manners, and is possessed of great national pride. He is naturally brave, provided his heart be in the cause which he espouses; but he is easily excited to tumultuary violence, and is very unwilling to submit to the restraints of discipline. In prosperity he is apt to give way to supineness and false confidence; but in adversity which might overwhelm others, he will often display great courage and surprising resources. He is very slow in his operations, and often ruins enterprises by temporizing. In all the provinces except those of the north, the inhabitants are extremely indolent, and possess a most invincible hatred of labour. They are fond of amusements, dancing and cards being the favourite recreations. Theatrical exhibitions are not very popular, being generally insipid. They are still attached to the bull-fight, but this cruel amusement is not now so common as formerly. It will however prevail as long as the country remains in its present state of ignorance. Dancing has acquired a national character; and to this day the Spaniard has many an allegorical dance, borrowed from the Moors. The pleasures of society are chiefly sought at evening parties, where only slight refreshments are presented; and indeed, both in eating and drinking, the Spaniards are remarkably temperate. Music also forms one of their principal amusements, the instrument most generally used being the guitar. Castanets are also extremely common, and are employed with great dexterity and address in the national dances. The music of the country is not remarkable, being almost altogether light melodies, with a slight accompaniment from the guitar. Spanish architecture, from its being a mixture of the Moorish and Gothic styles, has somewhat affected the architecture of other countries. The innumerable churches scattered over the country are generally in the Gothic taste, but more light, from its conjunction with the Moorish. Many of them are fine edifices; but the most remarkable architectural monument of Spain is the palace of the Escorial, which is built entirely in the Roman or Vitruvian style. Spain has produced few great painters, which is somewhat remarkable, considering the poetical character of the people. Murillo, Velasquez, and Lope de Vargas have acquired a fame which will endure wherever painting is appreciated. There is at Madrid an academy for painting, sculpture, and architecture, and the royal palace and Escorial have galleries; but it does not appear that these arts are much cultivated in the present day.

The literature of Spain, in the days of her greatness, was almost on a level with that of any other country in Europe; but it has now sunk to a very low condition. The ballad is what the early Spanish writers most excelled in; and this is characterized by romantic fervour, frequently of an oriental character. The language is peculiarly fitted to express the dignified and the pathetic, but its solemn dignity frequently seduces the writer into bombast. No language has such a store of ballads as the Spanish; but they are, particularly the early ones, little more than mere relations of chivalrous deeds. The wars with the Moors form the subject of an endless number of these ballads, which the chivalrous nature of the people of Spain during the middle ages brought to a state of excellence unequalled in any country in Europe. The song was the natural growth of the warlike period of Spain, and served to commemorate warlike exploits; but they were of a very simple character until the period of the conquest of Naples, when they assumed a more lyrical form. The national drama has always been peculiar, consisting chiefly of religious comedies founded on the lives of saints. There are however some noble comedies of an historical nature. The perfection of the intrigue is what the Spanish writers chiefly value; but their plots are con-

Spalatro
||
Spallan-
zani.

structed without any regard to the unities. The drama acquired its greatest celebrity from Lope de Vega and Calderon. In romance, Spain has accomplished much. The perfection of Spanish prose is to be found in the works of the inimitable Cervantes. After his time, and when the Bourbons ascended the throne, the literature declined with the state, and may be said to have remained ever since in a similar state of inactivity. Spain possesses at the present day few writers known beyond their own country. Jovellanos on political economy, Campany in philology, Llorente in history, Morales in mathematics, have done much to rouse a spirit of reflection; and Juan Valdez is called the Anacreon of Spain.

SPALATRO, a city of the ancient province of Dalmatia, and the capital of a circle of the same name, which extends over 2060 square miles, and contains 84,980 inhabitants. This city is situated on a peninsula, and is powerfully fortified both by nature and art. It incloses the space where formerly stood the extensive palace of Diocletian, the Roman emperor. It is now the seat of an archbishop, has a cathedral and several other churches, a seminary, and six religious houses, all for Catholics. It has narrow and crooked streets, 1500 large and antique houses, and 7400 inhabitants. It has considerable trade in salted meat, oil, wine, and fruit. The harbour is secure, and protected by two strong bastions. Lat. 43. 34. 30. Long. 15. 49. 25.

SPALDING, a town in the district of Holland, and county of Lincoln, ninety-seven miles from London. It stands near the mouth of the river Welland, which is navigable to the town. Of the adjacent district, the soil is rich, but marshy. Besides corn, chiefly oats, it produces much flax and hemp. Spalding has a fine old church, a spacious market-place, much frequented every Saturday. The famous Dr. Bentley was for a short time master of Spalding school. The inhabitants of the town were in 1811, 4330; in 1821, 5207; and in 1831, 6497.

SPALLANZANI, LAZZARO, a celebrated naturalist, was born at Scandiano, in the duchy of Modena, on the 12th of January 1729. He began his studies in his native country, and at the age of fifteen, went to Reggio de Modena, where he was instructed in rhetoric and philosophy by the Jesuits, who contended with the Dominicans in order to secure his attachment. His thirst for knowledge determined him to go to Bologna, where his relative Laura Bassi, a woman highly celebrated for her genius, eloquence, and skill in natural philosophy and mathematics, was one of the most distinguished professors of Italy. Under this enlightened guide, he was taught to prefer the study of nature to that of her commentators, judging of the real value of the commentary by its resemblance to the original. He availed himself of the wisdom of that lady's counsels, the happy effects of which he very soon experienced. Spallanzani's taste for philosophy was not exclusive, for he carefully studied his own language, became a proficient in the Latin tongue, and attached himself above every other to the Greek and French. By the advice of a father whom he ardently loved, he applied himself to jurisprudence; but being urged by Antonio Vallisnieri to renounce his vocation, by procuring the consent of his father, he gave himself up to the study of mathematics with more zeal than ever, at the same time devoting himself to the study of languages, both living and dead.

It was not long before he was known all over Italy, and, what is seldom the case, his own country first made that estimate of his talents which they justly merited. In the year 1745, he was chosen professor of logic, metaphysics, and Greek, in the university of Reggio, where he taught during ten years, devoting every moment of his leisure to the study and contemplation of the works of nature. The attention of Haller and Bonnet was fixed by his observa-

The army of Spain, once the most formidable and best organized in Europe, is now comparatively in a low state. It is, however, represented as the best organized part of her establishment, the pay being regular, and the officers experienced. In the present unsettled state of the country it is impossible to form any estimate of its actual numbers. Besides the regular army, there is a large body of militia called royalist volunteers, who have frequently proved of great service as light troops. The navy now exists only in name: in 1823 there was but one ship of the line, which, being sent out to South America, surrendered to the Peruvian government.

(R. R. R.)

Spallan-
zani.

tions on the animalculæ of infusions, the latter assisting him in his laudable career, and ever after distinguishing him as one of the learned interpreters of nature. He was invited to the university of Modena in 1760; and some years after he declined to accept of the advantageous offers made to him by the academy of Petersburg, as well as similar ones from Coimbra, Parma, and Cesena. He preferred his native spot, and therefore continued at Modena till the year 1768, and saw raised up by his care a generation of men constituting at that time the glory of Italy, among whom we find Venturi, Belloni, Lucchesini, and Angelo Mazzo.

In 1765, while he resided at Modena, he published his "Saggio di Osservazioni Microscopiche concernenti il Sistema di Needham e di Buffon;" in which he establishes, by a number of the most ingenious and solid experiments, the *animality of microscopic animalculæ*. This work was sent by the author to Bonnet, who drew from it a prediction respecting the future celebrity of Spallanzani, which he lived to see accomplished. This circumstance gave birth to the most intimate friendship, which lasted to the close of life, and constituted their chief happiness. During the same year he published a truly original work, entitled "De Lapidibus ab Aqua resilientibus;" in which he proves, by the most satisfactory experiments, and in opposition to the common received opinion, that what are called *ducks and drakes*, are not produced by the elasticity of the water, but by the effect naturally resulting from the change of direction experienced by the stone in its movement, after it has struck the water, and has been carried over the hollow of the cup formed by the concussion.

When the university of Padua was re-established upon a larger scale, the Count de Firmian was directed by the empress Maria Theresa, to invite Spallanzani to be professor of Natural History, although the chair was solicited by many celebrated characters. His reputation justified this preference, and immense crowds of students thronged to his lectures. He possessed much ingenuity, and his knowledge was of vast extent: his method was simple, but rigorous in its nature, and what he knew he connected with principles firmly established.

In the year 1776 he published, in two volumes quarto, his work entitled "Opuscoli di Fisica Animale e Vegetabile," containing the explanation of part of the microscopic observations which were previously given to the world. It must be admitted, that the art of accurate observation is one of the most difficult, and it cannot be denied, that it is at the same time the most necessary, and requires a rare combination of talents. These were possessed by Spallanzani in a remarkable degree, as is fully evinced by the researches which his admirable writings have recorded. The polite manner in which he conducted his dispute with Needham respecting the phenomena of generation, secured for him a high degree of applause. On this occasion, he treated of the influence of cold upon animals, and proved that the torpidity of some during winter, does not depend on the impression which the blood may receive from it, since a frog deprived of blood becomes torpid when reduced to the same cold state, by being immersed in ice,

Spallanzani.

and swims as formerly when restored to a proper degree of warmth.

Spallanzani travelled through Switzerland and the Grisons in the year 1779, after which he went to Geneva, spending a month with his friends, by whom his conversation was not less admired than his masterly writings. In the year 1780 he published, in two volumes quarto, his "*Dissertazioni di Fisica Animale e Vegetabile*," in which he unfolded the secrets of the interpretation of two very intricate phenomena, concerning the economy of animals and vegetables. To this study he was led, from some experiments made by him upon *digestion*; and he repeated the experiments of Reaumur on gallinaceous birds, remarking that the trituration which in this case is favourable to digestion, could not be a very powerful means. He perceived that the gizzard of those birds, by which the stones of fruit are pulverized, did not digest the powder thus formed; it being necessary that it should undergo a new operation in the stomach, previous to its becoming chyle for the production of the blood and other humours. This subject may be regarded as one of the most difficult in physiology, because the observer is always under the necessity of finding his way in the midst of darkness: the animal must be managed with care, that the derangement of the operations may be avoided; and when the experiments are completed with great labour, it is requisite that the consequences be well distinguished. In this work, Spallanzani analyses facts with scrupulosity, in order to ascertain their causes with certainty; comparing nature with his experiments, in order to form a correct judgment respecting them; laying hold of every thing essential to them in his observations, and measuring their solidity by the increase or diminution of supposed causes. John Hunter appears to have been greatly hurt by this work; and in the year 1785, he was induced to publish "*Some Observations upon Digestion*," in which he throws out some bitter sarcasms against the Italian naturalist. Spallanzani took ample revenge by publishing this work in the Italian language, and addressing to Caldani in 1788, "*Una Lettera Apologetica in Risposta alle Osservazioni del Signor Giovanni Hunter*." Here he exposed with great moderation, but at the same time with logic which nothing could resist, the mistakes and errors of the British physiologist.

The generation of animals and plants is discussed in the second volume of his *Dissertazioni*; where, by experiments as satisfactory as surprising, he proves the pre-existence of germs to fecundation, shewing also the existence of tadpoles in the females of five different species of frogs, in salamanders, and toads, before their fecundation. He likewise recounts the success of some artificial fecundations upon the tadpoles of those five species, and even upon a quadruped.

In the year 1781, he took the advantage of the academical vacation, for the purpose of making a journey, in order to add to the cabinet of Pavia. In the month of July he set out for Marseilles, where he began a new history of the sea, which presented him with many new and curious facts on numerous genera of the natives of the ocean. He went also to Finale, Genoa, Massa, and Carrara, to make observations on the quarries of marble, held by statuary in such estimation. He then returned to Spezzia, and brought from thence to Pavia a vast number of fishes, which he deposited in the cabinet of that city, wholly collected by himself. With the same view and success he visited the coasts of Istria in 1782, and the Apennine mountains the subsequent year, taking notice of the dreadful hurricanes, and the astonishing vapours by which that year became so noted in meteorology. The emperor Joseph, on examining this cabinet, presented Spallanzani with a gold medal. In 1785, he was offered the chair of natural history by the university of Padua, vacant by the death of Antonio Vallisnieri; but in order to prevent his acceptance of it, his salary was

doubled by the archduke, and he went to Constantinople with Zuliani, who had been appointed ambassador from the Venetian republic. He set out on the 21st of August, and on the 11th of October reached the Turkish metropolis, where he remained during eleven months. His attention was fixed by the physical and moral phenomena of this country, which were new even to Spallanzani. He wandered along the borders of the two seas, and ascended the mountains in the vicinity; he paid a visit to the island of Chalki, discovering to the Turks a copper mine, the existence of which they had never once conjectured. In the island of Principi, not far from Constantinople, he discovered an iron mine, of which the Turks were equally ignorant.

A voyage by sea was undoubtedly the safest, but the dangers to which he would be exposed by land were regarded as nothing when contrasted with the idea of being beneficial to science and to man. Having reached Bucharest, Mauroceni, the friend of science, received Spallanzani with marks of distinction, presented him with many rarities which the country produced, and supplied him with horses for travelling, with an escort of thirty troopers, to the confines of his own dominions. The philosopher passed by Hermanstadt in Transylvania, and on the 7th of December 1786, reached Vienna, where he remained during five days, and had two long conferences with the emperor. He was much esteemed by the nobility of that city, and respectfully visited by many literary characters. When he arrived at Pavia, the students advanced from the city-gates to meet him, and testified their joy at his return by repeated acclamations. He was almost instantly drawn to the auditory, and compelled to ascend the chair from which he had been accustomed to deliver his fascinating lectures; but in the midst of these demonstrations of joy and shouts of applause, he requested them to indulge him with that repose in his own house which was now so absolutely necessary. His students this year exceeded 500.

The reputation of Spallanzani was sufficiently brilliant to excite envy and detraction. His discoveries were too original and solid to be successfully disputed; but some of those who could not rival his successful ingenuity, began to call in question his integrity in the management of the museum at Pavia. A judicial investigation completely established the purity of his character; and it must be mentioned to his honour, that he had the fortitude to forget this event. His enemies in general confessed their mistake, renounced their unprovoked animosity, and still hoped to regain a friendship of which they had proved themselves so unworthy.

In 1792 he published at Pavia, in 6 vols. 8vo, his "*Viaggi alle due Sicilie, ed al alcune parti dell' Appennino*." Here we meet with what may be denominated a new volcanology. We are instructed how to measure the intensity of volcanic fires, and almost to touch the particular gas which tears those torrents of stone in fusion from the bowels of the earth, and raises them to the top of Mount Etna. This delightful work is closed by some important inquiries into the nature of swallows, the mildness of their dispositions, the rapidity of their flight; discussing the celebrated problem respecting their remaining torpid during the winter season; proving that artificial cold, much more intense than what is ever naturally experienced in our climates, does not reduce these birds to the torpid state.

Things apparently impossible were discovered by Spallanzani. In the year 1795 he made one of this description, which he gave to the world in his "*Lettere sopra il Sospetto di un nuovo Senso nei Pippistrelli*." In that work we are informed that bats, deprived of sight, act with the same precision in every instance as those which have their eyes; that they shun in the same manner the most trivial obstacles, and also know where to fix themselves when their flight is terminated. Several philosophers confirmed these

Spallanzani.

Spalmadori astonishing experiments, from which a suspicion arose, that these animals must have a new sense, as it appeared to *Spanheim*. *Spallanzani* that the other known senses could not compensate for the want of sight; but he was afterwards inclined to think, in consequence of Professor Jurin's experiments on the organ of hearing in bats, that in this particular instance the sense of hearing might possibly supply the want of sight.

He published many other works, which we cannot here enumerate.¹ He had nearly finished an account of his voyage to Constantinople, and had collected many valuable materials for a history of the sea, when his life and labours were brought to a termination. He was seized with a retention of urine, on the 30th of February 1799, and next morning was so far deprived of the use of his faculties, that he only enjoyed a sound mind during very short intervals. *Tourdes* and *Scarpa* did every thing to save him, which could be produced by the joint exertions of genius, experience, and friendship, but in vain. He died on the twelfth of the same month, after having completed the seventieth year of his age. His works have been translated into a great variety of languages, and he was enrolled as a member of many foreign academies.

SPALMADORI, a small island situated between the continent of Asia Minor and the island of Scio. Long. 26. 7. E. Lat. 38. 36. N.

SPAN, a measure taken from the space between the thumb and the tip of the little finger when both are stretched out. The span is estimated at three hand-breadths, or nine inches.

SPANDAU, a town of Prussia, in the government of Potsdam. It is a strongly fortified place, and is the chief arsenal of the kingdom. It stands on a peninsula, formed by the junction of the river Spree with the Havel. There are manufactures of all descriptions of arms, for the use of the government, and some private establishments for making silk goods, together with several breweries and distilleries. In the fortress is the state-prison; and there are institutions for the punishment of offenders, by keeping them to hard labour. The town contains 540 houses, with 6750 inhabitants. Lat. 53. 33. 7. Long. 13. 36. 40. E.

SPANDRELL, the solid work on each haunch of an arch, to keep it from spreading.

SPANHEIM, **EZEKIEL**, a very learned writer, was born at Geneva on the 7th of December 1629. His father, *Frederic Spanheim*, a distinguished theologian, was successively professor of divinity at Geneva and Leyden. The son accompanied him to the latter university, and there distinguished himself by his proficiency in solid learning. His early reputation procured him the professorship of eloquence at Geneva. He took possession of this chair in 1651; but he only retained it for a few months, the elector palatine *Charles Louis* having appointed him tutor to his only son. This task he discharged to the entire satisfaction of the elector, by whom he was also employed in divers negotiations at foreign courts. In 1677 he entered into the service of the elector of Brandenburg, who in 1680 sent him as envoy extraordinary to the court of France, and soon after made him a minister of state. After the peace of Ryswyck, he was again sent on an embassy to France, where he continued from the year 1697 to 1702. The elector of Brandenburg having during that interval assumed the title of king of Prussia, conferred on him the title and dignity of a baron. In 1702 he left France, and was sent as ambassador to England, which he had previously visited on more than one occasion. He died in London on the 7th of November 1710, at the age of eighty-one. It is surprising, that in discharging the duties of a public minister with so

much exactness, and amidst so many different journeys, he could find sufficient time to write the various books which he published. It may be said of him, that he acquitted himself in his negotiations like a person who had nothing else in his thoughts; and that he wrote like a man who had spent his whole time in his study. His works display a very profound and variegated erudition. The most elaborate of them is entitled, "*Dissertationes de Præstantia et Usu Numismatum antiquorum*," first printed at Rome in quarto in the year 1664. The best edition, extending to two volumes folio, was printed at London in 1706-17. Another valuable work is his "*Orbis Romanus*," of which the best edition is that of London, 1704, 4to. He translated the *Cæsars* of *Julian* into French, and illustrated them with annotations. He likewise contributed notes on *Aristophanes*, *Callimachus*, and some other Greek writers, of whom he did not himself publish editions.

SPAR, in *Mineralogy*, a name given chiefly to some of the crystallized combinations of lime, as the carbonate and the fluuate; the former being called simply lime spar, the latter fluor spar, or Derbyshire spar, from the name of the place where it is found in greatest abundance.

SPARTA, or **LACEDÆMON**, the capital of the country of Laconia in Greece, an ancient and most renowned state, the inhabitants of which have been in all ages celebrated for the singularity of their laws and character. The history of Sparta for many ages is entirely fabulous; and the authentic accounts commence only with the celebrated lawgiver *Lycurgus*, who flourished about 870 B. C.

After his death, the first important transaction which we find mentioned in the Spartan history is the Messenian war, which commenced in the year 752 B. C., and ended in the total reduction of the Messenian territory. During this period, according to some authors, a great change took place in the government of Sparta. This was the creation of the ephori, which is ascribed to one of the kings named *Theopompus*. Perceiving that there was a necessity for leaving magistrates to execute the laws, when the kings were obliged to be in the field, he appointed the magistrates above mentioned, who afterwards made so great a figure in the state. One great privilege of the ephori was, that they did not, like all other magistrates, rise up at the presence of the kings: another was, that if the kings offended against the laws, the ephori took cognizance of the offence, and inflicted a suitable punishment. From the first election of the ephori the year was denominated, as at Athens from the first election of the archons.

The conquest of Messenia gave Sparta the superiority over the rest of the states, excepting only that of Athens, which for a long time continued to be a very troublesome rival; but the contests between these two rival states have been so fully related under the article **ATTICA**, that nothing more is requisite to be added in this place. In the time of the Persian war, *Leonidas* as the Spartan king, distinguished himself in such a manner, as to become the admiration not only of that but of every succeeding age. It being resolved in a general council to defend the straits of *Thermopylæ* against the Persians, 7000 foot were put under the command of *Leonidas*; of whom, however, only 200 were Spartans. *Leonidas* did not think it practicable to defend the pass against such multitudes as the Persian king commanded; and therefore privately told his friends, that his design was to devote himself to death for his country. *Xerxes* advancing near the straits, was strangely surprised to find that the Greeks were resolved to dispute his passage; for he had always flattered himself, that on his approach they would betake themselves to flight, and not attempt to oppose his innumerable forces. Still however

Spar,
Sparta.

The his-
tory of
Sparta
mostly fa-
bulous till
the time of
Lycurgus.

Leonidas
undertakes
to defend
the straits
of *Ther-
mopylæ*
against the
Persians.

¹ Biographie Universelle, tom. xliii. p. 246, where a catalogue of *Spallanzani*'s works may be found.

Sparta. entertaining some hopes of their flight, he waited four days without undertaking any thing, on purpose to give them time to retreat. During this interval, he used his utmost endeavours to gain and corrupt Leonidas, promising to make him master of Greece if he would espouse his interest. His offers being rejected with contempt and indignation, the king ordered him by a herald to deliver up his arms. Leonidas, in a style and with a spirit truly laconical, answered, "Come thyself, and take them." Xerxes, transported with rage at this reply, commanded the Medes and Cissians to march against them, seize them all alive, and bring them to him in fetters. The Medes, not able to stand the shock of the Greeks, soon betook themselves to flight. In their room, Hydarnes was ordered to advance with that body which was called *Immortal*, and consisted of 10,000 chosen men; but when these assailed the Greeks, they succeeded no better than the Medes and Cissians, being obliged to retire with great slaughter. The next day the Persians, reflecting on the small number of their enemies, and supposing so many of them to be wounded that they could not possibly maintain a second fight, resolved to make another attempt; but, with all their efforts, they could not make the Greeks give way; on the contrary, they were themselves put to a shameful flight. The valour of the Greeks exerted itself in a manner so extraordinary, that Xerxes is said to have three times leaped from his throne, apprehending the entire destruction of his army.

The Persians repulsed with great slaughter.

They are shown a way over the hill to surround the Greeks.

Having lost all hopes of forcing his way through troops that were determined to conquer or die, he was extremely perplexed and doubtful what measures he should adopt in this posture of affairs, when one Epialtes, in expectation of a great reward, came to him, and discovered a secret passage to the top of the hill which overlooked and commanded the Spartan forces. The king immediately ordered Hydarnes thither with his select body of 10,000 Persians; who, marching all night, arrived at break of day, and possessed themselves of that advantageous post. The Phocæans, who defended this pass, being overpowered by the enemy's numbers, retired with precipitation to the very top of the mountain, prepared to die gallantly. But Hydarnes, neglecting to pursue them, marched down the mountain with all possible expedition, in order to attack in the rear those who defended the straits. Leonidas being now apprised that it was impossible to withstand the enemy, obliged the rest of his allies to retire; but he himself remained with the Thespians, Thebans, and 300 Lacedæmonians, all resolved to die with their leader; who, being told by the oracle, that either Sparta should be destroyed or the king lose his life, determined, without the least hesitation, to sacrifice himself for his country. The Thebans indeed remained against their inclination, being detained by Leonidas as hostages; for they were suspected to favour the Persians. The Thespians, with their leader Demophilus, could not be prevailed upon to abandon Leonidas and the Spartans. The augur Megistias, who had foretold the event of this enterprise, being pressed by Leonidas to retire, sent home his only son; but he remained himself, and died by Leonidas. Those who were left did not indulge any hope of conquering or escaping, but looked upon Thermopylæ as their grave; and when Leonidas, exhorting them to take some nourishment, said, that they should all sup together with Pluto, they with one accord raised a shout of joy, as if they had been invited to the banquet.

Leonidas killed with all his men.

Xerxes, after pouring out a libation at the rising of the sun, began to move with the whole body of his army, as he had been advised by Epialtes. Upon their approach, Leonidas advanced to the broadest part of the passage, and fell upon the enemy with such undaunted courage and resolution, that the Persian officers were obliged to stand behind the divisions which they commanded, in order to

prevent the flight of their men. Great numbers of the enemy falling into the sea, were drowned; others were trampled under foot by their companions, and very many killed by the Greeks; who, knowing they could not avoid death upon the arrival of those who were advancing to fall upon their rear, made prodigious efforts of valour. In this action fell the brave Leonidas; which Abrocomes and Hyperanthes, two of the brothers of Xerxes, observing, advanced with great resolution to seize his body, and carry it in triumph to Xerxes. But the Lacedæmonians, more eager to defend it than their own lives, repulsed the enemy four times, killed both the royal brothers, with many other commanders of distinction, and rescued the body of their beloved general out of the enemy's hands. But in the mean time, the army that was led by the treacherous Epialtes, advancing to attack their rear, they retired to the narrowest part of the passage, and all drawing together, except the Thebans, posted themselves on a rising ground. In this place they made head against the Persians, who assaulted them on all sides, till at length, not vanquished, but oppressed and overwhelmed by numbers, they all fell, except one who escaped to Sparta, where he was treated as a coward and traitor to his country; but he afterwards made a glorious reparation in the battle of Plataea, where he distinguished himself in an extraordinary manner. Some time after, a magnificent monument was erected at Thermopylæ, in honour of those brave defenders of Greece, with two inscriptions; the one general, and relating to all those who died on this occasion, importing, that the Greeks of Peloponnesus, to the number only of 4000, made head against the Persian army, consisting of 3,000,000. The other related to the Spartans in particular, and was composed by the poet Simonides, to this purport: "Go, passenger, and acquaint the Spartans that we died here in obedience to their just commands." At those tombs a funeral oration was yearly pronounced in honour of the departed heroes, and public games were celebrated with great solemnity. In these none but the Lacedæmonians and Thespians had any share, to show that they alone were concerned in the glorious defence of Thermopylæ.

At the end of the 77th Olympiad, a most dreadful earthquake happened at Sparta, in which, according to Diodorus, 20,000 persons lost their lives; and Plutarch avers, that only five houses were left standing in the whole city. On this occasion the Helotes, or slaves, whom the Spartans had all along treated with the utmost cruelty, attempted to revenge themselves, by taking up arms, and marching directly to the ruins of the city, in hopes of cutting off at once those who had escaped from the earthquake. But their attempt was defeated by the prudence of the Spartan king Archidamus; for observing that the citizens were more desirous of preserving their effects than taking care of their own lives, he caused an alarm to be sounded, as if he had known that an enemy was at hand. On this the citizens armed themselves in haste with such weapons as they could come at; and having marched a little way from the city, met the Helotes, whom they soon compelled to retire. The latter however knowing that they had now no mercy to expect from those who had already treated them with such cruelty, resolved to defend themselves to the last. Having therefore seized a sea-port town in Messenia, they from thence made such incursions into the Spartan territories, that they compelled those imperious masters to ask assistance from the Athenians. This was immediately granted; but when the Spartans saw that the skill of the Athenians in besieging towns was much greater than their own, they became jealous, and dismissed their allies, declaring that they had now no further occasion for their services. On this the Athenians left them in disgust; and as the Helotes and Messenians did not choose to come to an engagement with a Spartan army in the

A dreadful earthquake in Sparta.

War with the Helotes.

Sparta. field, but took shelter in their fortified places, the war was protracted for upwards of ten years. The Helotes were at last reduced to their former misery; and the Messenians were obliged to leave Peloponnesus, on pain of being likewise made slaves. These poor people were then received by the Athenians, who granted them Naupactus for their residence, and afterwards brought them back to a part of their own country, from whence in the course of the Peloponnesian war they had driven the Spartans.

With the Athenians and Persians. The Peloponnesian war commenced in the year 431 B. C.; but for its details we must refer to the article ATTICA. This war ended most unfortunately for the Athenians; for their city was taken and dismantled. Thus were the Spartans raised to the highest pitch of glory; and in the reign of Agesilaus, they seemed to be on the point of subverting the Persian empire. But here their good fortune and their views of empire were suddenly checked. Agesilaus had carried on the war in Asia with the greatest success; and as he would hearken to no terms of accommodation, a Persian governor named Tithraustes, having first attempted in vain to bribe the king, dispatched Timocrates the Rhodian with fifty talents into Greece, in order to try whether he could there meet with any persons less incorruptible than the Spartan monarch. This agent found many who inclined to accept his offers; particularly in Thebes, Corinth, and Argos. By distributing the money in a proper manner, he inflamed the inhabitants of these three cities against the Spartans; and the Thebans listened to his terms with the greatest readiness. They saw that their antagonists would not of their own accord break with any of the states of Greece, and did not choose to begin the war themselves, because the chiefs of the Persian faction were unwilling to be accountable for the event. For this reason they persuaded the Locrians to invade a small district which lay in dispute betwixt the Phocians and themselves. The Phocians accordingly invaded Locris; the Locrians applied to the Thebans, and the Phocians to the Spartans. The latter were glad of an opportunity of breaking with the Thebans; but met with a much warmer reception than they expected. Their old general Lysander, who had reduced Athens, was defeated and slain, along with a thousand of his soldiers. On this disaster Agesilaus was recalled, and was obliged to relinquish all hopes of conquering the Persians. His return changed the fortune of the war so much, that all the states began to grow weary of a contest from which nobody derived any advantage except the king of Persia. In a short time a treaty was concluded, known in history by the name of the peace of Antalcidas. The terms of this treaty were highly disadvantageous and dishonourable to the Greeks; for even the Spartans, though successful in Greece, had lost a great battle at sea with the Persian fleet under Conon the Athenian, and this event entirely broke their power in Asia.

A general combination against Sparta. By the peace of Antalcidas, the government of Bœotia was taken from the Thebans, which they had for a long time enjoyed; and they were so much provoked, that at first they absolutely refused to accede to the treaty; but as Agesilaus made great preparations to invade them, they at last thought proper to comply. It was not however long before a new war commenced, which threatened the total subversion of the Spartan state. As, by the peace of Antalcidas, the king of Persia had in a manner guaranteed the sovereignty of Greece to Sparta, this republic very soon began to exercise its power to the utmost extent. The Mantineans were the first who felt the weight of their resentment, although they had been their allies and confederates. In order to find a pretext for making war against them, they commanded them to quit their city, and to retire into five old villages, which, they said, had served their forefathers, and where they would live in peace themselves, and give no umbrage to their neighbours. As they refused to obey,

Peace of Antalcidas.

Hostilities recommenced.

an army was sent against them to besiege their city. The siege was continued through the summer with very little success on the part of the Spartans; but having during the winter season dammed up the river on which the city stood, the water rose to such a height, as either to overflow or throw down the houses; and the Mantineans were thus compelled to submit to the terms prescribed to them, and to retire into the villages. The Spartan vengeance next fell on the Phliasiens and Olynthians, whom they forced to come into such measures as they thought proper. After this they assailed the Thebans, and, by attempting to seize on the Piræum, drew the Athenians also into the quarrel. But here their career was arrested: the Thebans had been taught the art of war by Chabrias the Athenian; so that even Agesilaus himself took the command of the Spartan army in vain. At sea they were defeated by Timotheus the son of Conon; and by land the battle of Leuctra put an end to the superiority which Sparta had retained over Greece for nearly five hundred years.

Sparta.

After this dreadful defeat, the Spartans had occasion to exert all their courage and resolution. The women and nearest relations of those who were killed in battle, instead of spending their time in lamentations, shook each other by the hand, while the relations of those who had escaped from the battle hid themselves among the women; or if they were obliged to go abroad, they appeared in tattered clothes, with their arms folded, and their eyes fixed on the ground. It was a law among the Spartans, that such as fled from battle should be degraded from their honours, should be constrained to appear in garments patched with divers colours, to wear their beards half-shaved, and without resistance to suffer any to beat them who pleased. At present however this law was suspended; and Agesilaus, by his prudent conduct, kept up the spirits of the people, at the same time that by his skill in military affairs he checked the progress of the enemy. Yet, during the lifetime of Epaminondas the Theban general, the progress of the war was greatly to the disadvantage of the Spartans; but he being killed at the battle of Mantinea, all parties soon became desirous of peace. Agesilaus did not long survive; and with him, we may affirm, perished the glory of Sparta. Soon after this all the states of Greece fell under the power of Alexander the Great; and the Spartans, as well as the rest, having become corrupt, and lost their martial spirit, became a prey to domestic tyrants, and to foreign invaders. They however maintained their ground with great resolution against the celebrated Pyrrhus king of Epirus; whom they repulsed for three days successively, though not without assistance from one of the captains of Antigonus. Soon after this, one of the kings of Sparta named Agis, perceiving the universal degeneracy that had taken place, made an attempt to restore the laws and discipline of Lycurgus, by which he supposed the state would be restored to its former glory. But though at first he met with some appearance of success, he was in a short time tried and condemned by the ephori as a traitor to his country. Cleomenes, however, who ascended the throne in 216 B. C. accomplished the reformation which Agis had in vain attempted. He suppressed the ephori; cancelled all debts; divided the lands equally, as they had been in the time of Lycurgus; and put an end to the luxury which prevailed among the citizens. But at last he was overborne by the number of enemies which surrounded him; and being defeated in battle by Antigonus, he fled to Egypt, where he put an end to his own life. With him perished every hope of retrieving the affairs of Sparta: the city for the present fell into the hands of Antigonus; after which a succession of tyrants gained and lost the ascendancy, till at last all disturbances were ended by the Romans, who reduced Greece to the condition of a province.

The power of Sparta entirely broken.

Agis and Cleomenes attempt in vain to restore it.

Institutions of Lycurgus.

It only remains to make some observations on the cha-

Sparta. racter, manners, and customs of the Spartans, which, as they were founded on the laws of Lycurgus, may best be learned from a view of those laws.

His laws concerning religion.

The institutions of Lycurgus were divided into twelve tables. The first comprehended such of the Spartan laws as regarded religion. The statues of all the gods and goddesses, even to Venus herself, were represented in armour; in order that the people might conceive a military life the most noble and honourable, and not attribute, as other nations did, sloth and luxury to the gods. As to sacrifices, they consisted of things of very small value; for which Lycurgus himself gave this reason, that want might never hinder them from worshipping the gods. They were forbidden to make long or rash prayers, and were enjoined to ask no more than that they might live honestly and discharge their duty. Graves were permitted to be made within the bounds of the city, contrary to the custom of most of the Greek nations; nay, they buried the dead near the temples, that all degrees of people might be made familiar with death, and not conceive it such a dreadful thing as it was generally esteemed elsewhere. On the same account, the touching dead bodies, or assisting at funerals, made none unclean, but these were held to be as innocent and honourable duties as any other. There was nothing thrown into the grave with the dead body; magnificent sepulchres were forbidden; nor did they even permit an inscription, however plain or modest. Tears, sighs, outcries, were not allowed in public, because they were thought dishonourable in Spartans, whom their lawgiver would have to bear all things with equanimity. Mourning was limited to eleven days; on the twelfth the mourner sacrificed to Ceres, and threw aside his weeds. In favour of such as were slain in the wars, however, and of women who devoted themselves to a religious life, there was an exception allowed as to the rules before mentioned; for such had a short and decent inscription on their tombs. When a number of Spartans fell in battle, at a distance from their country, many of them were buried together under one common tomb; but if they fell on the frontiers of their own state, their bodies were carefully removed to Sparta, and interred in their family sepulchres.

Concerning the division of land.

II. Lycurgus divided all the country of Laconia into 30,000 equal shares: the city of Sparta he divided into 9000, as some say; into 6000 according to others; and as a third party will have it, into 4500. The intent of the legislator was, that property should be equally divided among the citizens, so that none might be powerful enough to oppress his fellows, or any be in such necessity, as thus to be exposed to the danger of corruption. With the same view he forbade the buying or selling these possessions. If a stranger acquired a right to any of these shares, he might quietly enjoy it, provided he submitted to the laws of the republic. The city of Sparta was unwall'd, Lycurgus trusting it rather to the valour of its citizens than to the art of masons. As to the houses, they were very plain; for their ceilings could only be wrought by the axe, and their gates and doors only by the saw; and their utensils were to be of a similar make, that luxury might have no instruments among them.

Of the citizens, children, &c.

III. The citizens were to be neither more nor less than the number of city lots; and if at any time there happened to be more, they were to be led out in colonies. As to children, their laws were equally harsh and unreasonable; for a father was directed to carry his new-born infant to a certain place, where the gravest men of his tribe looked upon the infant; and if they perceived its limbs straight, and thought it had a wholesome look, they then returned it to its parents to be educated; otherwise it was thrown into a deep cavern at the foot of the mountain Taygetus. This law seems to have had one very good effect, namely, that of making women very careful, when they were with child, of either eating, drinking, or exercising to excess: it made

also excellent nurses; for which they were in mighty request throughout Greece. Strangers were not allowed to reside long in the city, that they might not corrupt the Spartans by teaching them new customs. For the same reason, citizens were also forbidden to travel, unless the good of the state required it. Such as were not bred up in their youth according to the law, were not allowed the liberty of the city, because they held it unreasonable, that one who had not submitted to the laws in his youth should receive the benefit of them when a man. They never preferred any stranger to a public office; but if at any time they had occasion for a person not born a Spartan, they first made him a citizen, and then preferred him.

IV. Celibacy in men was infamous, and punished in a most extraordinary manner; for the old bachelor was constrained to walk naked, in the depth of winter, through the market-place: while he did this, he was obliged to sing a song in disparagement of himself; and he had none of the honours paid him which otherwise belonged to old age, it being held unreasonable, that the youth should venerate him who was resolved to leave none of his progeny behind him, to revere them when they grew old in their turn. The time of marriage was also fixed; and if a man did not marry when he was of full age, he was liable to an action; as were such also as married above or below their condition. Such as had three children enjoyed great immunities; such as had four were free from all taxes whatsoever. Virgins were married without portions; because neither want should hinder a man, nor riches induce him, to marry contrary to his inclinations. When a marriage was agreed on, the husband committed a kind of rape upon his bride. Husbands went for a long time, secretly and by stealth, to the beds of their wives, that their love might not be quickly and easily extinguished. Husbands were allowed to lend their wives; but the kings were forbidden to exercise this license. Some other laws of the like nature there were, which, as they were evidently against modesty, so they were far from producing the end for which Lycurgus designed them; since, though the men of Sparta were generally remarkable for their virtue, the Spartan women were as generally decried for their boldness and contempt of decency.

V. It was the care of Lycurgus, that the Lacedæmonians, Education from their very birth, should be inured to conquer their appetites. For this reason he directed, that nurses should accustom their children to spare meals, and now and then to fasting; that they should carry them, when twelve or thirteen years old, to those who should examine their education, and who should carefully observe whether they were able to remain alone in the dark, and whether they had conquered all other follies and weaknesses incident to children. He directed, that children of all ranks should be brought up in the same way; and that none should be more favoured in food than another, that they might not, even in their infancy, perceive any difference between poverty and riches, but consider each other as equals, and even as brethren, to whom the same portions were assigned, and who, through the course of their lives, were to fare alike. The youths alone were allowed to eat flesh: older men ate their black broth and pulse; the lads slept together in chambers, and, after a manner somewhat resembling that recently in use in Turkey for the Janizaries. Their beds, in the summer, were very hard, being composed of the reeds plucked by the hand from the banks of the Eurotas: in winter their beds were softer, but by no means downy, or fit to induce immoderate sleep. They ate altogether in public; and in case any abstained from coming to the tables, they were fined. It was likewise strictly forbidden for any to eat or drink at home before they came to the common meal; even then each had his proper portion, that every thing might be conducted with gravity and decency. The black broth was the great rarity of the Spartans, which was composed of salt, vinegar,

Sparta.

Of celibacy and marriage.

Education of their children.

Sparta. blood, &c. so that in our times, it would be esteemed a very unsavoury soup. If they were moderate in their eating, they were likewise so in their drinking; of which thirst was the sole measure; for never any true Lacedæmonian thought of drinking for pleasure. As for drunkenness, it was both infamous and severely punished; and slaves were compelled to drink to excess, that young men might be disgusted by the beastliness of this vice. When they retired from the public meal, they were not allowed any torches or lights, because it was expected, that men who were perfectly sober should be able to find their way in the dark; and besides, it gave them a facility of marching without light.

Of their diet, clothing, &c. VI. As the poor were fed as well as the rich, so the rich could wear nothing better than the poor. They neither changed the fashion nor the materials of their garments, which were made for warmth and strength, not for gallantry and show, and to this custom even their kings conformed; for they were not entitled to mark their dignity by splendid apparel, but were contented that their virtue should distinguish them rather than their clothes. The youths wore a tunic till they were twelve years old; they were afterwards furnished with a cloak, which was to serve them for a year; and their clothing was in general so thin, that a Lacedæmonian vest became proverbial. Boys were accustomed to go without shoes: when they grew up, they were indulged with them, if the manner of life which they led required it; but they were always inured to run without them, as also to climb up and slide down steep places with bare feet. The very shoe they used was of a particular form, plain and strong. Boys were not permitted to wear their hair; but when they arrived at the age of twenty, they suffered their hair and beard to grow. Baths and anointing were not in much use among the Lacedæmonians; the river Eurotas supplied the former, and exercise the latter. In the field, however, their sumptuary laws did not take place so strictly as in the city; for when they went to war, they wore purple habits; they put on crowns when they were about to engage the enemy; they also wore rings, but only of iron. Young women wore their vests or jerkins only to their knees, or, as some think, not quite so low; a custom which both Greek and Roman authors censure as indecent. Gold, precious stones, and other costly ornaments, were permitted only to common women; which permission was the strongest prohibition to women of virtue, or to those who affected to be thought virtuous. Virgins went abroad without veils, with which married women were always covered. In certain public exercises, in which girls were admitted as well as boys, they were both obliged to perform naked. Plutarch apologises for this custom, urging, that there could be no danger from nakedness to the morals of youths whose minds were fortified and habituated to virtue.—One of Lycurgus's principal views in this institution, was to eradicate the very seeds of civil dissension in his republic. Hence proceeded the equal division of estates enjoined by him; hence the contempt of wealth, and the neglect of other distinctions, as particularly birth; distinctions which, in other commonwealths, frequently produce tumults and confusions that shake their very foundation. He considered the people of his whole state as one great family.

Obedience to their superiors. VII. Though the Spartans were always free, yet it was with this restriction, that they were subservient to their own laws, which bound them as strictly in the city, as soldiers, in other states, were bound by the rules of war in the camp. In the first place, obedience to their superiors was most rigidly exacted in Sparta. This they regarded as the very basis of government, and without which neither laws nor magistrates could much avail. Here old age conferred an indubitable title to honour: to the old men the youth rose up whenever they came into any public place; they gave way to them when they met them in the streets, and were silent whenever their elders spoke. As all children were

looked upon as the children of the state, so all the old men had the authority of parents: they reprehended whatever they saw amiss, not only in their own, but in other people's children; and by this method Lycurgus provided, that as youth are everywhere apt to offend, they might be nowhere without a monitor. The laws proceeded still farther: if an old man was present where a young one committed a fault, and did not reprove him, he was punished equally with the delinquent. Among the youths there was one of their own body, or at most two years older than the rest, who was styled *iren*: he had authority to question all their actions, to look strictly to their behaviour, and to punish them if they did amiss; neither were their punishments light, but, on the contrary, very severe. Thus the youths were rendered hardy, and accustomed to bear stripes and rough usage. Silence was highly commended at Sparta, where modesty was held to be a most becoming virtue in young people; nor was it restricted only to their words and actions, but extended to their very looks and gestures; Lycurgus having particularly directed, that they should look forward, or on the ground, and that they should always keep their hands within their robes. A stupid inconsiderate person, one who would not listen to instruction, but was careless of whatever the world might say of him, the Lacedæmonians treated as a scandal to human nature: with such a one they would not converse, but threw him off as a rotten branch, and worthless member of society.

VIII. The plainness of their manners, and their being so much addicted to war, made the Lacedæmonians less fond of the sciences than the rest of the Greeks. That of a soldier was the only reputable profession in Sparta; a mechanic or husbandman was thought a low person. The reason of this was, that they imagined professions which required much labour, some constant posture, being continually in the house, or always near a fire, weakened the body and depressed the mind; whereas a man brought up hardily, was equally fit to attend the service of the republic in time of peace, and to fight its battles in time of war. Such occupations as were necessary to be followed for the benefit of the whole, as agriculture and the like, were left to their slaves the Helotes; but for curious arts, and such as serve only to luxury, they would not so much as suffer them to be introduced in their city; rhetoricians, augurs, and dealers in money were consequently excluded. The Spartans admitted none of the theatrical diversions among them; they would not bear the representation of evil even to produce good; but other kinds of poetry were admitted, provided the magistrates had the perusal of pieces before they were communicated to the public.

Above all things, they affected brevity of speech, and accustomed their children, from their very infancy, never to express themselves in more words than were strictly necessary; whence a concise and sententious oratory is to this day styled *Laconic*. In writing they used the same conciseness. We have a signal instance in a letter of Archidamus to the Eleans, when he understood they had some thoughts of assisting the Arcadians. It ran thus: "Archidamus to the Eleans. It is good to be quiet." And therefore Epaminondas thought he had reason to glory in having forced the Spartans to abandon their monosyllables, and to lengthen their discourses.

The greatest part of their education consisted in giving their youth right ideas of men and things: the *iren* or master proposed questions, and either commended the answers that were made him, or reproved such as answered weakly. In these questions, all matters, either of a trivial or abstruse nature, were equally avoided; and they were confined to such points as were of the highest importance in civil life; such as, who was the best man in the city? wherein lay the merit of such an action? and, whether this or that hero's fame was well-founded? Harmless raillery was greatly en-

Sparta. encouraged; and this, joined to their short manner of speaking, rendered Laconic replies universally admired.

Music was much encouraged; but in this, as in other things, they adhered to that which had been in favour with their ancestors. They would not permit their slaves to learn either the tune or the words of their most admired odes; or, which is all one, they would not permit them to sing them if they had learned them. Though the youth of the male sex were much cherished and beloved, as those that were to build up and continue the future glory of the state, yet in Sparta it was a virtuous and modest affection, untinged with that sensuality which was so scandalous at Athens. The good effects of this part of Lycurgus's institutions were seen in the union that reigned among his citizens; and which was so extraordinary, that even in cases of competition, it was hardly known that rivals bore ill-will to each other; but, on the contrary, their love to the same person produced a secondary friendship among themselves, and united them in all things which might be for the benefit of the person beloved.

Some authors have accused this great lawgiver of encouraging theft in his institutions; which, they say, was not held scandalous among the Spartans, if it were so dexterously managed as that the person was not detected in it. But this is certain, and seems to be a strong contradiction of the heinous charge, that when a theft was discovered, it was punished with the utmost severity: a person even suspected of it would endure the heaviest punishments rather than acknowledge it, and be branded with so base a crime.

Exercises. IX. The exercises instituted by law belong to the ninth table. In these all the Greeks were extremely careful, but the Lacedæmonians in a degree beyond the rest; for if a youth, by his corpulence, or any other means, became unfit for these exercises, he underwent public contempt at least, if not banishment. Hunting was the usual diversion of their children; nay, it was made a part of their education, because it had a tendency to strengthen their limbs, and to render those who practised it supple and fleet. Dogs for hunting were reared with great care. They had a kind of public dances, in which they exceedingly delighted, and which were common alike to virgins and young men: indeed, in all their sports, girls were allowed to divert themselves with the youths; insomuch, that, at darting, throwing the quoit, pitching the bar, and such like robust diversions, the women were as dexterous as the men. For the manifest oddity of this proceeding, Lycurgus assigned no other reason, than that he sought to render women, as well as men, strong and healthy, that the children they brought forth might be so too. Violent exercises, and a laborious kind of life, were only enjoined the youth; for when they were grown up to men's estate, that is, were upwards of thirty years old, they were exempted from all kinds of labour, and enjoyed themselves wholly either in affairs of state, or in war. They had a method of whipping, at a certain time, young men in the temple of Diana, and about her altar; which, however palliated, was certainly unnatural and cruel. It was esteemed a great honour to sustain these flagellations without weeping, groaning, or showing any sense of pain; and so strong was the thirst of glory in these young minds, that they frequently suffered death without shedding a tear, or breathing a sigh. A desire of overcoming all the weaknesses of human nature, and thus rendering his Spartans not only superior to their neighbours, but to their species, runs through many of the institutions of Lycurgus; and by keeping this principle in view, we are enabled to understand many circumstances that must otherwise appear inexplicable.

Money, &c.

X. Gold and silver were, by the constitutions of Lycurgus, rendered of no value in Sparta. Of the danger of riches he was so well apprised, that he rendered the very

possession of them penal; but as some standard of value was necessary, he directed an iron coinage, whereby the Spartans were supplied with the useful money, and at the same time had no temptation to covetousness afforded them; for a very small sum was sufficient to load a couple of horses, and a great one must have been kept in a barn or warehouse. The introduction of all foreign money was also prohibited, that corruption might not enter under the name of commerce. The most ancient method of dealing, namely, by barter or exchange of one commodity for another, was preserved by law in Sparta long after it had fallen into disuse everywhere else. Interest was forbidden in the Spartan commonwealth; where they had also a law against alienation of lands, accepting presents from foreigners, even without the limits of their own country, and when their authority and character might well seem to excuse them.

XI. Such of the laws of Sparta as related to courts of justice may be brought under the eleventh table. Thirty years must have passed over the head of him who had a right to concern himself in juridical proceedings. Young men were thought unfit for them; and it was even considered as indecent for a man to have any fondness for law-suits, or to be busying himself at the tribunals, when he had no affairs there of his own. By these rules Lycurgus thought to exclude litigiousness, and to prevent that multiplicity of suits which seems to be a necessary evil in other states. As young people were not permitted to inquire about the laws of other countries, and as they were hindered from hearing judicial proceedings in their courts, so they were likewise forbidden to ask any questions about, or to endeavour to discover, the reasons of the laws by which themselves were governed. Obedience was their duty; and to that alone they would have them kept. Men of abandoned characters, or who were notoriously of ill fame, lost all right of giving their votes in respect of public affairs, or of speaking in public assemblies; for they could not believe that a man unprincipled in private life could be better affected to his country than to his neighbour.

XII. Before the age of thirty, a Spartan was not capable of serving in the army, as the best authors agree; though some think that the military age is not well ascertained by ancient writers. Their forces were forbidden to march at any time before the full-moon; the reason of which law is very hard to be discovered, if indeed it had any reason at all, or was not rather founded on some superstitious opinion, that this conjuncture was more lucky than any other. They were likewise forbidden to fight often against the same enemy. This was one of the wisest maxims in the political system of Lycurgus; and Agesilaus, by offending against it, destroyed the power of his country, and lost her that authority which for many years she had maintained over the rest of Greece; for, by continually warring against the Thebans, to whom she had an inveterate hatred, he at last beat them into the knowledge of the art of war, and enabled them, under the command of Epaminondas, to maintain for a time the principality of Greece. With maritime affairs they were forbidden to meddle, though the necessity of things compelled them, in process of time, to transgress this institution, and by degrees to transfer to themselves the dominion of the sea as well as of the land; but, after the Peloponnesian war, they again neglected naval affairs, from a persuasion that sailors and strangers corrupted those with whom they conversed. As they never fortified Sparta, they were not ready to undertake sieges: fighting in the field was their proper province, and, while they could there overcome their enemies, they rightly conceived that nothing could hurt them at home. In time of war, they relaxed somewhat of their strict manners of living. The true reason for this was, in all probability, that war might be less burdensome to them; for, as we have more than once observed, a strong desire to render them bold and warlike was

Military service.

Sparta.

Spartianus, the reigning passion of their legislator. They were forbidden to remain long encamped in the same place, as well to hinder their being surprised, as that they might be more troublesome to their enemies, by wasting every corner of their country. They slept all night in their armour; but their outguards were not allowed their shields, that, being unprovided of defence, they might not dare to sleep. In all expeditions they were careful in the performance of religious rites; and after their evening meal was over, the soldiers sung together hymns to their gods. When they were about to engage, the king sacrificed to the Muses, that, by their assistance, they might be enabled to perform deeds worthy of being recorded to the latest times. The army then advanced in order to the sound of flutes, which played the hymn of Castor. The king himself sung the pæan, which was the signal to charge. This was done with all the solemnity imaginable, and the soldiers were sure either to conquer or die, nor indeed had they any other choice; for if they fled they were infamous, and in danger of being slain, even by their own mothers, for disgracing their families. In this consisted all the excellency of the Spartan women, who, if possible, exceeded in bravery the men, never lamenting over husbands or sons, if they died honourably in the field, but deploring the shame brought on their house, if either the one or the other escaped by flight. The throwing away a shield also inferred infamy; and mothers, when they embraced their departing sons, were wont to caution them, that they should either return armed as they were, or be brought back so when they were dead; for, as we have observed, such as were slain in battle were nevertheless buried in their own country. When they put an enemy to flight, they pursued no longer than till victory was certain; because they would seem to fight rather for the honour of conquering, than of putting their enemies to death. According to their excellent rules of war, they were bound not to spoil the dead bodies of their enemies; but in process of time, this, and indeed many other of their most excellent regulations, fell into desuetude. He who overcame by stratagem, offered up an ox to Mars; whereas he who conquered by force, offered up only a cock; the former deed being esteemed more manly than the latter. After forty years' service, a man was exempted from military duty; and consequently, if they commenced their career at thirty, the Spartans were not considered as invalids till they attained the age of seventy.

SPARTIANUS, **ÆLIUS**, a Latin historian, who flourished in the reign of Diocletian, about the year 290. He is known as the author of the lives of Hadrian and Ælius Verus; and to him are likewise ascribed several other lives contained in the collection of "Historiæ Augustæ Scriptores." See Fabricii *Bibliotheca Latina*, tom. iii. p. 95.

SPECIES, in *Logic*, a relative term, expressing an idea which is comprised under some general one called a *genus*.

SPECIES, in *Algebra*, are the letters, symbols, marks, or characters, which represent the quantities in any operation or equation. This short and advantageous way of notation was chiefly introduced by Vieta, about the year 1590; and by means of it he made many discoveries in algebra.

SPECIES, in *Optics*, the image painted on the retina by the rays of light reflected from the several points of the surface of an object, received by the pupil, and collected in their passage through the crystalline, &c. It has been a matter of dispute among philosophers, whether the species of objects which give the soul an occasion of seeing, be an effusion of the substance of the body; a mere impression which they make on all bodies under certain circumstances; or whether they are not some more subtle body, such as light. The moderns have decided this point by the invention of artificial eyes, in which the species of objects are received on paper, in the same manner as in the natural eye.

SPECIFIC, in *Philosophy*, that which is peculiar to any thing, and distinguishes it from all others.

SPECIFICS, in *Medicine*. By specifics is not meant such as infallibly and in all patients produce salutary effects. Such medicines are not to be expected, because the operations and effects of remedies are not formally inherent in them, but depend upon the mutual action and reaction of the body and medicine upon each other; hence the various effects of the same medicine in the same kinds of disorders in different patients, and in the same patient at different times. By specific medicines we understand such medicines as are found to be more uniform in their effects than others in any particular disorder.

SPECIFIC Gravity, is a term much employed in the discussions of modern physics. It expresses the weight of any particular kind of matter, as compared with the weight of the same bulk of some other body of which the weight is supposed to be familiarly known, and is therefore taken for the standard of comparison. The body generally made use of for this purpose is pure water. See **CHEMISTRY** and **HYDRODYNAMICS**.

SPECTACLES, in *Dioptrics*, an instrument consisting of two lenses set in silver, horn, &c. to assist the defects of the organ of sight. Old people, and others who have flat eyes, use convex spectacles, which cause the rays of light to converge so as to meet upon the retina; whereas myopes, or short-sighted people, use concave lenses for spectacles, which cause the rays to diverge, and prevent their meeting before they reach the retina. See **OPTICS**.

SPECTRA, images presented to the eye after removing them from a bright object, or closing them. When any one has long and attentively looked at a bright object, as at the setting sun, on closing his eyes, or removing them, an image, which resembles in form the object he was attending to, continues some time to be visible. This appearance in the eye we call the ocular spectrum of that object. These ocular spectra are of four kinds: 1st, Such as are owing to a less sensibility of a defined part of the retina, or spectra from defect of sensibility. 2d, Such as are owing to a greater sensibility of a defined part of the retina, or spectra from excess of sensibility. 3d, Such as resemble their object in its colour as well as form; which may be termed direct ocular spectra. 4th, Such as are of a colour contrary to that of their object, which may be termed reverse ocular spectra.

SPECTRE, an apparition, or something supposed to be preternaturally visible to human sight, whether the ghosts of dead men or beings superior to man. See **APPARITIONS**.

SPECULATIVE, something relating to the theory of some art or science, in contradistinction to practical.

SPECULUM for reflecting telescopes. See **OPTICS** and **TELESCOPE**.

SPEED, **JOHN**, an English historian, was born at Farington in Cheshire, in the year 1542. He was by trade a tailor, and a freeman of the company of merchant tailors in the city of London. In 1606 he published his "Theatre of Great Britain," which was afterwards reprinted in folio, under the title of "The Theatre of the Empire of Great Britain." In 1614 appeared his "History of Great Britain;" and in 1616 he published in octavo, "The Cloud of Witnesses, or, the Genealogies of Scripture." These genealogies were prefixed to many editions of the English translation of the Bible; and King James gave him a patent for securing the property to him and his heirs. He had twelve sons and six daughters; and died in 1629. He was interred in the church of St. Giles's, Cripplegate, London, where a monument was erected to his memory.

SPELDHURST, a large parish in the hundred of Washlingstone and county of Kent, thirty-three miles distant from London. A great part of the township of Tunbridge

Species.

Specific
||
Speldhurst.

Spelling
||
Spence.

Wells is comprehended in it, to which circumstance it owes its increased inhabitants, who were, in 1801, 1618; in 1811, 1901; in 1821, 2297; and in 1831, 2640.

SPELLING, in *Grammar*, that part of orthography which teaches the true manner of resolving words into their syllables.

All words are either simple or compound, as *use, disuse; done, undone*; and the rules for dividing each must be such as are derived from the analogy of language in general, or from the established custom of speaking; which, for the English language, are reduced to the following rules: 1. A consonant between two vowels must be joined with the latter in spelling, as *na-ture, ve-ri-ly, ge-ne-rous*; except, however, the letter *x*, which is joined to the first, as in *flax-en, ox-en, &c.*, and compound words, as in *up-on, un-used, &c.* 2. A double consonant must be divided, as in *let-ter, man-ner, &c.* 3. Those consonants which can begin a word, must not be parted in spelling, as in *de-fraud, re-prove, di-stinct*: this rule, however, is sometimes found to fail; for though *gn* begins a word, as in *gnaw, gnat, &c.*, yet it must be divided in spelling, as in *cog-ni-zance, ma-lig-ni-ty, &c.* 4. Those consonants which cannot begin a word must be divided, as *ld* in *sel-dom, lt* in *mul-ti-tude, mp* in *tem-per, rd* in *ar-dent*; but in final syllables there are exceptions, as *tl* in *ti-tle, dl* in *han-dle, &c.* 5. When two vowels come together, and are both of them distinctly sounded, they must be separated in spelling, as *ed* in *wing-ed, edst* in *de-li-ver-edst, ing* in *hear-ing, ance* in *de-li-ver-ance, &c.* 6. The grammatical terminations or endings must be separated in spelling, as *ed* in *wing-ed, edst* in *de-li-ver-edst, ing* in *hear-ing, ance* in *de-li-ver-ance, &c.* 7. Compound words must be resolved into their simple and component words, as *up-on, in-to, ne-ver-the-less, not-with-stand-ing, &c.*

SPELMAN, SIR HENRY, an eminent antiquary, was descended from an ancient family, and born at Congham, near Lynn in Norfolk, about the year 1561. He was knighted by King James I. who had a particular esteem for him on account of his known capacity for business; and he employed him several times in Ireland in public affairs. When he was about fifty years of age, he went to reside in London; where falling into a study to which his own genius had always inclined him, he collected all such books and MSS. as concerned the subject of antiquities, either foreign or domestic. In 1626, he published the first part of his well-known "*Glossarium Archaologicum*," which he never carried beyond the letter L; because, as some have suggested, he had made remarks under "*Magna Charta*," and "*Maximum Consilium*," which could not then have appeared without giving offence. Upon his death, all his papers came into the hands of his son Sir John Spelman, a gentleman who had abilities to have completed his father's design, if death had not prevented him. The second part was afterwards published by Sir William Dugdale, but with all the marks of a scanty unfinished performance. The next work which he undertook was an edition of the English Councils; of which he published the first volume in 1639, leaving the second volume, as well of this as of his Glossary, to be published by Dugdale. The second volume appeared in 1664. Spelman wrote several other works relating to ancient laws and customs, and died in 1641. His Treatise concerning Tithes, and his History of Sacrilege, deserve a passing notice. His Posthumous Works were published at Oxford, in folio, in the year 1698, under the inspection of Mr. Gibson, afterwards Bishop of London.

SPENCE, JOSEPH, an eminent writer, was born in the year 1698, but his family-history remains in obscurity. He was probably educated at Winchester, for he became a fellow of New College, Oxford, where he took the degree of A.M. in 1727. During the same year he published a small volume entitled "*An Essay on Pope's Odyssey*, in which some particular beauties and blemishes of that work are considered." This essay was greatly admired by his con-

Spence.

temporaries, and it procured him the friendship of Pope. Spence was elected professor of poetry in 1728, and held that office ten years, which is as long as the statutes will allow. His account of Stephen Duck was first published in 1731; but it was afterwards much altered, and prefixed to an edition of Duck's Poems.

About this time he travelled into Italy as tutor to the Earl of Lincoln, afterwards Duke of Newcastle. In 1736 he republished Gorboduc, at Mr. Pope's desire, with a preface giving an account of its author, the Earl of Dorset. He quitted his fellowship in 1742, upon being presented by his college to the rectory of Great Harwood in Buckinghamshire. He never resided on his living; but paid it an annual visit, distributing large sums of money among the poor, and providing for many of their children. The same year he was appointed professor of modern history at Oxford. In 1747 he published a large folio volume entitled "*Polymetis*; or, an Inquiry concerning the Agreement between the Works of the Roman Poets and the Remains of ancient Artists; being an attempt to illustrate them mutually from each other." This work was treated by Gray with a contempt which it did not deserve. He raises objections because the author did not illustrate his subject from Greek writers; that is, because he failed to execute what he never undertook. By the publication of his *Polymetis*, Spence is said to have cleared L.1500. He was installed prebendary of the seventh stall at Durham on the 24th May 1754. He published the same year, "*An Account of the Life, Character, and Poems, of Mr. Blacklock, Student of Philosophy in the University of Edinburgh*;" which was afterwards prefixed to Blacklock's Poems. The prose pieces which he printed in the Museum he collected and published, together with some others, in a pamphlet called, "*Moralities*, by Sir Harry Beaumont." Under the same name, he published, "*Crito, or a Dialogue on Beauty*," and "*A particular Account of the Emperor of China's Gardens near Pekin*, in a letter from F. Attiret, a French missionary now employed by that emperor to paint the apartments in those gardens, to his friend at Paris." Both these tracts are printed in Dodsley's *Fugitive Pieces*, as is also "*A Letter from a Swiss Officer to his friend at Rome*;" which Mr. Spence first published in the Museum. In 1758, he published "*A Parallel, in the Manner of Plutarch, between a most celebrated man of Florence and one scarce ever heard of in England*." The Florentine was Magliabecchi, and the other individual was Robert Hill the Hebrew tailor. This tract is also to be found among the *Fugitive Pieces*. During the same year he made a journey into Scotland, which he described in an affectionate letter to Mr. Shenstone, published in Hull's *Collection of Letters*, 1778. In 1764 he was very well described by James Ridley, in his admirable *Tales of the Genii*, under the name of *Phesoi Ecneps* (his name read backwards), dervise of the groves. A letter from Mr. Spence to that ingenious moralist, under the same signature, is preserved in the third volume of "*Letters of eminent Persons*." In 1768 he published "*Remarks and Dissertations on Virgil, with some other classical observations, by the late Mr. Holdsworth*." On the 20th of August the same year he was unfortunately drowned in a canal in his garden at Byfleet in Surrey. He was found flat upon his face at the edge of the canal, where the water was so shallow as not even to cover his head. The fatal accident, it was supposed, for he was quite alone, was occasioned by a fit.

More than half a century after his death, appeared his "*Anecdotes, Observations, and Characters of Books and Men, collected from the Conversation of Mr. Pope, and others. With notes and a life of the author by S.W. Singer*." London, 1820, 8vo. Mr. Malone had likewise prepared an edition of this work, and, after his death, it was published during the same year.

Spencer
||
Spenser.

SPENCER, JOHN, a very learned theologian, was born at Bocton-under-Blean, in Kent, in the year 1630. From the grammar school of Canterbury he was removed to Corpus Christi College at Cambridge, where he was entered on the 25th of March 1645. Having taken the degree of A.B. in 1648, and of A.M. in 1652, he was chosen a fellow in 1655. In 1660 he preached a sermon before the university, and during the same year it was published under the title of "The righteous Ruler." He afterwards published a learned and curious work, entitled, "A Discourse concerning Prodigies." To the second edition, corrected and enlarged, he added "A Discourse concerning vulgar Prophecies." Lond. 1665, 8vo. During the same year, he proceeded D.D. In 1667, he was presented by his college to the rectory of Landbeach, and on the 3d of August elected master of the college. About a month after his election, he was preferred by the king to the archdeaconry of Sudbury, in 1672 to a prebend of Ely, and in 1677 to the deanery of that church. In 1669 he had published a Latin dissertation concerning Urim and Thummim. But his most elaborate work is *De Legibus Hebræorum Ritualibus, et earum Rationibus, libri tres*. Cantab. 1685, 2 tom. fol. An edition, with the author's additions and improvements, was published at Cambridge in 1727; and several editions, one by Pfaff, were printed on the continent. "It is," as Mr. Orme has remarked, "a very learned, but a very dangerous work; the great object of which is to show, that the Hebrew ritual was almost entirely borrowed from the Egyptians, and accommodated to the taste and prejudices which the Jews had acquired among that people. The same hypothesis had been stated by Maimonides, a philosophizing Jew, in his *More Nevochim*, and was greedily laid hold of by Sir John Marsham, in his *Canon Chronicus Egyptiacus*. A masterly refutation of the work of Spencer was furnished by Witsius, in his *Ægyptiaca*; and Shuckford, in his *Connections*, supplies also many arguments on the same side. Warburton partly espoused the system of Spencer, and replied to Witsius, for which he is very properly censured by Dr. Magee, in his work on the Atonement. Socinians and infidels have made very liberal use of the work and arguments of Spencer."¹

Dr. Spencer died on the 27th of May 1695, in the sixty-third year of his age. He was a great benefactor to his college, to which he bequeathed an estate that had cost him L.3600. He married Hannah, the daughter of Isaac Pullen of Hertford, and had a son and a daughter, who both died before their father.

SPENCER CAPE, a pointed rocky cape, the east point of entrance into Spencer's Gulf on the south shore of New Holland. Long. 136. 56. E. Lat. 35. 18. S.

SPENCER'S GULF, a large gulf on the south coast of New Holland, which extends 185 miles into the interior of the country, in a north-east direction. The entrance between Cape Catastrophe on the west, and Cape Spencer on the east, is forty-eight miles wide. Captain Flinders traced it to within eight miles of its termination.

SPENSER, EDMUND, one of the greatest of English poets, was born in East Smithfield, about the year 1533. There is no record in which the admirers of his genius may trace the incidents of his early years; but there is reason to suppose that they were clouded by poverty and dependence. On the 20th of May 1519, he entered Pembroke Hall, Cambridge, in the humble character of a sizer; a circumstance which is alone sufficient to rescue those luckless scholars from abject despondency, and to render them respectable in the eyes of their more fortunate companions. Some poems, in a collection of fugitive pieces entitled "The Theatre for Worldlings," which appeared during this

year, are ascribed to Spenser, upon internal evidence. Spenser. On the 10th of January 1552-3 he took the degree of A.B., and on the 26th of June 1576 that of A.M. From a letter of his friend Gabriel Harvey, himself a poet of some reputation in his time, it appears that, in consequence of having made enemies, who had both the will and power to injure him, he quitted Cambridge in despair of academical preferment. He had luckily some friends in the north of England, among whom he now found a temporary asylum. Whether he was received as an honoured guest, or compelled to turn his learning to account in the way of tuition, is unknown; but the latter supposition is the more probable of the two.

During his retirement in the north, Spenser wrote "The Shepherd's Calendar." Nothing is more common than for poets to deprecate the barbarity of a phantom, and to be reduced to despair, because some angelic nonentity turns a deaf ear to their entreaties; but it is said that Rosalind was a real mistress, at whose feet Spenser sighed in vain. The successful rival of the needy sonneteer was, in all likelihood, some substantial yeoman. At this period of his history, Harvey advised him to try his fortune in London; and it is probable that he abandoned without reluctance, the scene of his unrequited passion. Upon his arrival in the metropolis, he was fortunate enough to obtain an introduction to Sir Philip Sidney, who invited him to become his guest at Penshurst, the seat of the family in Kent. As a token of gratitude for this hospitality the "Shepherd's Calendar," published in 1579, was "entitled to the noble and virtuous gentleman, most worthy of all titles, Maister Philip Sidney."

Till long after the time of Spenser, the poet depended upon the casual gratuities of distinguished persons, who sometimes exerted their influence in procuring for a favourite bard some less precarious means of subsistence. Recommended, as it is conjectured, by the Earl of Leicester, the poet went to Ireland with Arthur Lord Grey of Wilton, who was appointed deputy of that kingdom in 1580. Spenser was the secretary of the viceroy, and discharged the duties of his office with greater promptitude and exactness than poets usually display in the ordinary business of life. His "View of the State of Ireland," a treatise written in the form of a dialogue, displays no inconsiderable portion of political sagacity. By the interest of Lord Grey, Leicester, and Sidney, Spenser obtained, in 1586, a grant of three thousand and twenty-eight acres of the forfeited estates of the Earl of Desmond. This piece of good fortune was embittered by the death of his patron, the gallant Sidney, who fell in the same year at the battle of Zutphen. The pastoral elegy of *Astrophel*, sacred to the memory of the departed hero, although not published until 1591, was probably written when the grief of the poet was at the height. It was provided by the royal patent, that those who profited by the forfeiture should reside upon the lands that were allotted to them. According to this arrangement, Spenser proceeded to a place named Kilcolman, in the county of Cork. This exile, to what was then little better than a region of barbarians, was cheered by a visit from the renowned Sir Walter Raleigh. At the suggestion, it may be presumed, of his distinguished guest, whom perhaps he accompanied to England, the poet soon exchanged his Hibernian solitude for the splendours of a court. In 1590 were published the first three books of the *Fairy Queen*; and the poet was afterwards presented by Raleigh to Queen Elizabeth, who conferred upon him a pension of fifty pounds a-year, then no despicable sum. The grant of this pension was discovered in the chapel of the Rolls by Mr. Malone, who has thus been enabled to clear the repu-

¹ Orme's *Bibliotheca Biblica*, p. 417. Edinb. 1824, 8vo.

Spenser. tation of Lord Burleigh from the stigma of having intercepted the bounty of his sovereign to the author of the *Fairy Queen*. Mr. Malone has also made it appear, that Queen Elizabeth had no poet-laureate; an appointment which was supposed to have been held by Spenser. In the sonnets annexed to the poem, is one to his new patron, "the right noble and valorous knight, Sir Walter Raleigh;" but Spenser does not forget to shed a grateful tear to the memory of Sidney. There is a sonnet addressed to the Countess of Pembroke, the darling sister of that accomplished person, for whose amusement he wrote his *Arcadia*. With mournful dignity, the poet acknowledges to the countess his many obligations to

—that most heroicke spirit,
The heauens pride, the glory of our daies.

During his absence in Ireland, to which kingdom he returned after the publication of the *Fairy Queen*, was printed a collection of Spenser's minor pieces, entitled, "Complaints: containing sundrie small Poemes of the Worlds Vanitie. Whereof the next page maketh mention. By Ed. Sp." Lond. 1591, 4to. This production was followed by *Daphnoida*, an elegy on the death of Douglas Howard, daughter of Henry Lord Howard. It is dated January 1, 1591-2. About this period, he is supposed to have paid a visit to his native country; after which a considerable space intervenes unmarked by incidents.

Being no longer a penniless rhymster, Spenser now wooed a kinder mistress than Rosalind. The lady, whose name is unknown, became his wife in 1594. The progress of this successful courtship is traced in his *Amoretti*, or *Sonnets*. In 1595 appeared the pastoral of "Colin Clout's come home again." The dedication of this production is erroneously dated 1591, as Mr. Todd satisfactorily proves. It is dedicated to Sir Walter Raleigh, who is introduced as the Shepherd of the Ocean. In 1596, he published four Hymns. He informs the Countess of Cumberland and the Countess of Warwick, to whom they are inscribed, that the two latter, composed in his riper years, and treating of heavenly love and beauty, were designed to atone for the two former, which were written in the heyday of his blood, and of which the subjects are sensual desire and earthly grace. In the same year were produced the fourth, fifth, and sixth books of the *Fairy Queen*. Of that magnificent poem, two additional imperfect cantos are all that can be found. Our limits prohibit the discussion of the question, whether the remaining six books, which would have completed the design, were destroyed by fire during the Irish rebellion, or left unfinished. Nor is there much utility in transcribing a long list of poems no longer extant, which are supposed to have shared their fate. In the course of this year, Spenser presented his *View of the State of Ireland* to the queen; but, for reasons not very clearly explained, that performance was not printed until thirty-five years after the author's death.

In a letter from Queen Elizabeth to the Irish government, dated September 30, 1598, which was discovered by Mr. Malone, Spenser is recommended to be sheriff of Cork. A royal recommendation is generally equivalent to a command; but the rebellion of Tyrone put a period to all the poet's hopes of dignity and emolument. To escape the fury of the insurgents, he abandoned his house in Kilcolman, leaving behind him one of his children, who had been forgotten in the terror of the moment. Having removed every thing else that it contained, the miscreants set fire to the building, and left the infant to perish in the flames. Spen-

ser did not long survive these multiplied calamities. On the 16th of January 1598-9, soon after his arrival in England, he died at an inn in King Street, Westminster. The expenses of his funeral were defrayed by the unfortunate Earl of Essex, who buried him in Westminster Abbey, near the remains of Chaucer; a spot on which he had always desired to take his last repose.¹

Spenser left two sons, Sylvanus and Peregrine. Hugolin, the son of the latter, was restored to his grandfather's estate by Charles II.; but, adhering to the infatuated successor of that monarch, he was outlawed, after the revolution, for high treason. The lands of the outlaw, however, were bestowed upon his cousin William, the son of Sylvanus, through the interest of Mr. Montague, afterwards Earl of Halifax. William Spenser was presented to the notice of Montague by Congreve. "The family of the Spensers," says Gibbon, "has been illustrated and enriched by the trophies of Marlborough, but I exhort them to consider the *Fairy Queen* as the most precious jewel in their coronet."

Of Spenser's personal character, we are in a great measure left to form our opinion from his works. Both the tendency and details of these are highly favourable to virtue; and the many chaplets he threw upon the bier of Sidney prove that he cherished the memory of his benefactor with pious care. It is easy to imagine gratitude allied to every other noble quality, and it is mere misanthropy to question the sincerity of tears that fall to those who can give no more; for it is vain to seek

—pensions from the tomb,
Or laurels from the dust.

There is, however, a dark spot on the fame of Spenser. From some original documents preserved in the Rolls Office at Dublin, it appears that the murder of his infant, his own ruin, despair, and death, are to be traced to his cupidity; for the outrage that was the immediate cause of these disasters, was perpetrated less from the hopes of plunder than the desire of vengeance for some unjust and oppressive attempts to add to his possessions.² Injustice and oppression were so habitual with the English settlers in Ireland, that it was not easy for Spenser to escape the general contamination.

This great poet is far from being a favourite of the general readers of modern times, who demand something of a more stimulating nature than the lives and adventures of the cardinal virtues. Indeed, to have made an interminable allegory interesting to thousands, must be allowed to be one of the greatest efforts of genius. This Spenser has accomplished; and his pages, if not devoured with trembling eagerness, are always perused with wonder, and often with delight, by the great majority of those whose suffrage is of any value. It has been urged that Arthur, the hero of the poem, instead of achieving the principal adventures, acts only as an auxiliary to others, and that either his character, or those of the twelve worthies, might with great propriety have been expunged; that the allegory often degenerates into mere description, without any occult meaning; and that the *ottava rima* of Tasso and Ariosto, with the addition of an Alexandrine, is a measure which is little adapted to the genius of the English language. There is however little rashness in predicting that the *Fairy Queen* will last as long as the English language itself.

An edition of Spenser's Works, with a glossary and a life of the author, and an essay on allegorical poetry, was published by John Hughes. Lond. 1715, 6 vols. 12mo. The *Fairy Queen*, with an exact collation of the two original

¹ Ben Jonson, in his *Conversations with Drummond*, stated, "that the Irish having rob'd Spenser's goods and burnt his house and a little child new born, he and his wyf escaped; and after, he died for lake of bread in King Street, and refused twenty pieces sent to him by my Lord of Essex, and said, 'He was sorrie he had no time to spend them.'"

² Hardiman's *Irish Minstrelsy, or Bardic Remains of Ireland*, vol. i. p. 320. Lond. 1831, 2 vols. 8vo.

Spermaceti
||
Sphinx.

Spice.
Spilsby.

editions, a life of the author by Dr. Birch, and a glossary, together with 32 plates from designs by Kent, must likewise be mentioned. Lond. 1751, 3 vols. 4to. Another edition of this poem, with notes critical and explanatory, was soon afterwards published by Ralph Church, A.M. Lond. 1758, 4 vols. 8vo. And about the same time appeared a new edition, with a glossary and notes explanatory and critical, by John Upton, A.M. Lond. 1758, 2 vols. 4to. An elaborate and complete edition of Spenser's Works was at length published by Mr. Todd. Lond. 1805, 8 vols. 8vo. Nor must we fail to direct the reader's more particular attention to Mr. Warton's "Observations on the Faerie Queen of Spenser," in 2 vols. 8vo. As a proof of the poet's continental reputation, we may here refer to *Spenser's Sonnetten, übersetzt durch Joseph von Hammer*. Wien, 1814, 8vo.

SPERMACETI, a whitish, unctuous, flaky substance, prepared from oil, but chiefly from the brains of a species of whale called *physeter macrocephalus*.

SPEUSIPPUS, an Athenian philosopher, the nephew and successor of Plato. Contrary to the practice of his master, Speusippus required from his pupils a stated gratuity. He placed statues of the Graces in the school which Plato had built. On account of his infirm state of health, he was commonly carried to and from the Academy in a vehicle. On his way thither he one day met Diogenes, and saluted him: the surly philosopher refused to return the salute, and told him, that such a feeble wretch ought to be ashamed to live; Speusippus replied, that he lived not in his limbs, but in his mind. At length being wholly incapacitated, by a paralytic stroke, for the duties of the chair, he resigned it to Xenocrates. He is said to have been of a violent temper, fond of pleasure, and exceedingly avaricious. Speusippus wrote many philosophical works, which are now lost, but which Aristotle thought sufficiently valuable to purchase at the expense of three talents. From a few fragments which remain of his philosophy, it appears that he adhered very strictly to the doctrine of his master.

SPEY, a river of Scotland, rises from a lake of the same name in Badenoch, and after a serpentine course of seventy-six miles, passes by Rothes castle, and falls into the German ocean at Garloch near Elgin.

SPHERE is a solid contained under one uniform round surface, every point of which is equally distant from a certain point in the middle called its *centre*; and is formed by the revolution of a semicircle about its diameter.

SPHERE, in *Astronomy*, that concave orb or expanse which invests our globe, and in which the heavenly bodies appear to be fixed, and at equal distance from the eye.

SPHEROID, in *Geometry*, a solid approaching to the figure of a sphere. It is generated by the entire revolution of a semi-ellipsis about its axis. When the revolution is made round the largest axis, the spheroid is called *prolate*; and when round the shortest, *oblate*. This last is the figure of the earth, and probably of all the planets.

SPHINCTER, in *Anatomy*, a term applied to a kind of circular muscles, or muscles in form of rings, which serve to close and draw up several orifices of the body, and prevent the excretion of the contents.

SPHINX, in fabulous history, a monster which had the head and breasts of a woman, the body of a dog, the tail of a serpent, the wings of a bird, the paws of a lion, and a human voice. It sprang from the union of Orthos with the Chimæra, or of Typhon with Echidna. The sphinx had been sent into the neighbourhood of Thebes by Juno, who wished to punish the family of Cadmus, which she persecuted with immortal hatred; and it laid this part of Bœotia under continual alarms, by proposing enigmas, and devouring the inhabitants, if unable to explain them. In the midst of their consternation the Thebans were told by

the oracle, that the sphinx would destroy herself as soon as one of the enigmas which she proposed was explained. In this enigma, she wished to know what animal walked on four legs in the morning, two at noon, and three in the evening. Creon king of Thebes promised his crown and his sister Jocasta in marriage to him who could deliver his country from the monster by a successful explanation of the enigma. It was at last happily explained by Oedipus, who observed, that man walked on his hands and feet when young, or in the morning of life; at the noon of life he walked erect; and in the evening of his days he supported himself by leaning on a stick. The sphinx no sooner heard this explanation than she dashed her head against a rock, and immediately expired. Some mythologists wish to unriddle the fabulous traditions about the sphinx by the supposition, that one of the daughters of Cadmus, or Laius, infested the country of Thebes, by her continual depredations, because she had been refused a part of her father's possessions. The lion's paw expressed, as they observe, her cruelty, the body of the dog her lasciviousness, her enigmas the snares which she laid for strangers and travellers, and her wings the dispatch which she used in her expeditions.

Among the Egyptians the sphinx was the symbol of religion, by reason of the obscurity of its mysteries; and on the same account the Romans placed a sphinx in the pro-naos or porch of their temples. Sphinxes were used by the Egyptians to show the beginning of the water's rising in the Nile: as it had the head of a woman and the body of a lion, it signified that the Nile began to swell in the months of July and August, when the sun passes through the signs of Leo and Virgo. There are several of these still to be seen; one in particular, near the Pyramids, much spoken of by the ancients. It is of a prodigious size, and cut out of the rock; the head and neck appear only at present, the rest of the body being hid in the sand. This, according to Thevenot, is twenty-six feet high, and fifteen feet from the ear to the chin: but Pliny assures us, the head was no less than 102 feet in circumference, and sixty-two feet high from the belly, and that the body was 143 feet long, and was thought to be the sepulchre of King Amasis. The learned Mr. Bryant observes, that the sphinx seems to have been originally a vast rock of different strata; which, from a shapeless mass, the Egyptians fashioned into an object of beauty and veneration.¹ The Egyptians used this figure in their building; from them the Greeks derived it, and afterwards improved it into an elegant ornament. It is also frequently used in modern architecture.

It may be proper to observe, that the sphinx of the Egyptians is said in the *Asiatic Researches*² to have been found in India. Colonel Pearse was told by Murari Pandit, a man of learning among the Hindoos, that the sphinx, there called *singh*, is to appear at the end of the world, and as soon as he is born will prey on an elephant; he is therefore figured seizing an elephant in his claws; and the elephant is made small, to show that the *singh*, even a moment after his birth, will be very large in proportion to it. But in opposition to this account given by Murari Pandit, the late Sir William Jones, the learned and illustrious president of the Asiatic Society, was assured by several Brahmins, that the figure taken for a sphinx was a representation of a lion seizing a young elephant.

SPICE, any kind of aromatic drug that has hot and pungent qualities; such as pepper, nutmeg, ginger, cinnamon, and cloves.

SPILSBY, a market-town of Lincolnshire, in the hundred of Bolingbroke and the division of Lindsay, thirty-one miles from the city of Lincoln, and 132 from London. It

¹ Bryant's Ancient Mythology, vol. iii. p. 532.

² Vol. ii. p. 334.

Spinage
li
Spinning.

stands on an eminence, commanding an extensive view towards the south. It is composed of four streets, uniting at the market-place, which is a square with a cross, consisting of a plain octagonal shaft, with a quadrangular base; and near to it is the town-hall, rebuilt in 1764, in which the quarter sessions for the division of Lindsay are held. The parish church is a large old edifice, including a chapel with some ancient monuments. There is a good market on Saturday. The population was, in 1801, 932; in 1811, 963; in 1821, 1234; and in 1831, 1384.

SPINAGE, or SPINACH. See HORTICULTURE.

SPINDLE, in *Geometry*, a solid body generated by the revolution of some curve line about its base or double ordinate; in opposition to a conoid, which is generated by the rotation of the curve about its axis or absciss, perpendicular to its ordinate. The spindle is denominated circular, elliptic, hyperbolic, or parabolic, according to the figure of its generating curve.

SPINET, or SPINETT, (Ital. *Spinetta*), an old-fashioned musical instrument, of which the brass and steel wires were struck by quills fixed to the tongues of the jacks that were moved by finger-keys. It was the predecessor of the harpsichord and the piano-forte.

SPINNING is the art of forming continuous threads by drawing out and twisting together filamentous materials. This was at first a manual art, and was practised in the earliest ages. The simple tool first made use of, consisted of a piece of wood, with its lower extremity of a conical form like a boy's top, and its upper portion long and tapering to a point, to which the fibres to be spun were fixed; this was termed a spindle, and in using was spun like a top to twist the threads. To the spindle an addition was soon made of the distaff, consisting of a piece of wood, round which the material to be spun was lapped. The distaff was held in the one hand of the spinner, while the other hand was engaged in drawing the fibres from the mass, and ever and anon giving fresh impetus to the motion of the spindle. This simple apparatus must have been early used, as, among the sculptures of the early Egyptian tombs, we find representations of females forming threads with the spindle; and singular though it be, the same apparatus may yet be found in a few places in Scotland, affording, in its toilsome progress, a striking contrast to the whirling wonders of the cotton-mill.

A great improvement in the use of the distaff and spindle, by which the spinner's hands were in a great measure left free to regulate the formation of the thread, was made by mounting the spindle in a frame, and using a larger wheel to drive it by a belt; and this again was further improved by using a treadle to effect the movement of the wheel by the foot of the spinner. No attempt, however, to introduce mechanism to supply the place of the skill and dexterity in manipulation, which the spinner could acquire only by assiduous practice, appears to have been made before the beginning of the eighteenth century. At that time there were in common use two kinds of spinning implements. The one, called the *large wheel*, was used in the spinning of wool and cotton, consisting of a large wheel or rim mounted in a frame, and having a belt to drive the spindle which projected from the side of the frame, and had the material to be spun affixed to its end. In spinning, the operator, usually a female, laid hold of the wool or cotton with the finger and thumb of her left hand, at a few inches distant from the spindle, and drew it towards her, while she turned the wheel with her right hand; she thus extended and twisted repeated portions, and as they were twisted, she, by guiding with her hand the thread she had formed, allowed it to be wound upon the spindle. Thus, from the carded cotton or wool, a loose flabby thread or *rove* was formed, which was again subjected to a similar drawing or extension, and twisted until reduced to a fine and compact thread. The other implement, called the *small* or *Saxon wheel*, was a more per-

fect apparatus, and was used for the spinning of flax; it had on its spindle a bobbin, on which the thread was wound, and a flyer revolving with greater rapidity than the bobbin to give the thread twist; a fixed distaff, on which the prepared flax was loosely rolled; and a treadle by which a rotatory motion was given to the wheel by the foot of the operator, whose hands were thus left at liberty to draw out the fibres of the flax in the requisite number to form the thread; in doing this, the fibres were, from time to time, moistened with saliva, to make them more readily combine.

Such were the implements used in Britain and elsewhere, when, about the year 1738, an ingenious mechanist, John Wyatt, made an attempt to substitute mechanism for the hands and the skill of the spinner. To him is due the honour of discovering the principle of roller-spinning; a principle which, forty years afterwards, was fully developed by the genius of Arkwright. The following account of Wyatt's invention, by his son Mr. Charles Wyatt, will shew to what extent he carried the principle of roller-spinning.

"In the year 1730, or thereabouts, living then at a village near Litchfield, our respected father first conceived the project, and carried it into effect; and in the year 1733, by a model of about two feet square, in a small building near Sutton Coldfield, without a single witness to the performance, was spun the first thread of cotton ever produced without the intervention of the human fingers, he, the inventor, to use his own words, '*being all the time in a pleasing, but trembling, suspense.*' The wool had been carded in the common way, and was *passed between two cylinders, from whence the bobbin drew it by means of the twist.*

"This successful experiment induced him to seek for a pecuniary connexion equal to the views that the project excited, and one appeared to present itself with a Mr. Lewis Paul, which terminated unhappily for the projector; for Paul, a foreigner, poor and enterprising, made offers and bargains which he never fulfilled, and contrived, in the year 1738, to have a patent taken out in his own name for some additional apparatus, a copy of which I send you; and in 1741, or 1742, a mill turned by two asses walking round an axis was erected in Birmingham, and ten girls were employed in attending the work. Two hanks of the cotton then and there spun are now in my possession, accompanied with the inventor's testimony of the performance. Drawings of the machinery were sent, or appear to have been sent, to Mr. Cave, for insertion in the *Gentleman's Magazine*.

"This establishment, unsupported by sufficient property, languished a short time, and then expired; the supplies were exhausted, and the inventor much injured by the experiment, but his confidence in the scheme was unimpaired. The machinery was sold in 1743. A work upon a larger scale, on a stream of water, was established at Northampton, under the direction of Mr. Yeoman, but with the property of Mr. Cave. The work contained 250 spindles, and employed fifty pairs of hands.

"The work at Northampton did not prosper. It passed, I believe, into the possession of a Mr. Yeo, a gentleman of the law, in London, about the year 1764; and, from a strange coincidence of circumstances, there is the highest probability that the machinery got into the hands of a person who, with the assistance of others, knowing how to apply it with skill and judgment, and to supply what might be deficient, raised upon it, by a gradual accession of profit, an immense establishment, and a princely fortune."

The principles of Wyatt's invention are contained in that portion of Paul's specification which we here quote: "The wool or cotton being thus prepared (by carding into slivers), one end of the mass, rope, thread, or sliver, is put betwixt a pair of rowlers, cillinders, or cones, or some such movements, which being twined round by their motion,

Spinning.

Spinning. draws in the raw mass of wool or cotton to be spun in proportion to the velocity given to such rowlers, cillinders, or cones. As the prepared mass passes regularly through or betwixt these rowlers, cillinders, or cones, a *succession* of other rowlers, cillinders, or cones, moving proportionably faster than the first, draw the rope, thread, or sliver, into any degree of fineness which may be required. Sometimes these successive rowlers, cillinders, or cones (but not the first) have another rotation besides that which diminishes the thread, yarn, or worsted, viz., that they give it a small degree of twist betwixt each pair, by means of the thread itself passing through the axis and center of that rotation. In some other cases only the first pair of rowlers, cillinders, or cones, are used, and then the bobbyn, spole, or quill, upon which the thread, yarn, or worsted is spun, is so contrived as to draw faster than the first rowlers, cillinders, or cones give, and in such proportion as the first mass, rope, or sliver is proposed to be diminished."

To appreciate rightly Wyatt's invention, we must take into consideration the state of the art at his day. No machine, except the household wheels, already described, then existed, and their useful effect depended on the skill and dexterity of the spinner. Wyatt's invention contained the germ of a self-acting and self-regulating principle; and the means which he used were so unlike any operation performed by the hands, that although unfortunately his success was only partial, he is yet entitled to our admiration for the originality of his genius. He did much for the art, if what he did prepared a foundation for Arkwright's superstructure.

The next invention was one in which an effort was made directly to imitate the action of the spinster, as exemplified in the wool-wheel, in drawing away the roving of wool until extended to the proper length, and, after having twisted it, winding it on the cope or spindle. This was the "Jenny" of Hargreaves, a poor weaver of Lancashire.

If we imagine many spindles to be set in motion by one wheel, and the ends of the rovings connected with these to be inserted between two pieces of wood, which, like the jaws of a vice, would hold them firmly, and by which they could all be drawn back at one time by the left hand of the spinner, while with his right hand he could drive the wheel which gives the spindles their motion, we shall have a good idea of the first spinning-jenny, which was indeed, no more than this. In process of time, however, the machine was rendered very different from the one first constructed. The spindles were increased from eight (the number in Hargreaves's original machine) to eighty, and upwards; the clove or clasp by which the slivers or rovings were held was improved in form, and mounted on a carriage, and made to run on a railway in the framing, the effect of which was more perfect equality of the thread, and a greater degree of precision in the process. The yarn when spun was built up in a conical form on the cope or spindle by a proper apparatus, and altogether the machine was very much improved. Still, with all its improvements, it was only a hand-wheel of many spindles. But as a hand-wheel it probably effected more good than it would have done had it been more complete. It still remained a domestic implement of small cost, and its use rapidly extended. The jenny was imperfect in so far that it could only be brought to act upon rovings, which required to be formed on the hand-wheel already described. This defect was soon remedied by the introduction of the *slubbing billy*, in which the parts of the jenny were reversed, the place of the clove or clasp being supplied by rollers, and the spindles being mounted in a frame running on a railroad. The card rolls or slivers were in this machine placed continuously on an inclined plane, formed by a travelling canvas, which conducted them up to the feeding rollers, placed at its highest point; and on passing through the feeding rollers the slivers were attached

to the spindles, which, receding from the rollers, twisted the slivers and formed rovings for the jenny. This machine is still used for forming the rove in wool-spinning.

The problem of automatic spinning, however, remained yet to be practically solved, and this solution was reserved for the genius of another man in poor circumstances,—Richard Arkwright.

The bad success of roller-spinning in the hands of Wyatt, a most ingenious man, would have deterred most men from again attempting it; but partial failure appears to have ever stimulated the persevering Arkwright to fresh exertion. He, a poor man, a barber by trade, unaided, almost uneducated, and totally unacquainted with mechanics, perfected a system of machine-spinning which ultimately raised the manufactures of his country to a height unexampled, and obtained for him honour and wealth.

Arkwright's principle of roller-spinning need not here be particularly described, as we shall have occasion to illustrate it more fully afterwards. It is only necessary generally to observe, that in this mode of spinning the material is extended to the requisite degree by rollers, and twisted and wound up by a flyer and bobbin, as in the small flax wheel, the drawing, the twisting, and the winding up being simultaneously carried on. Important as the invention of roller-spinning is, it is not on it alone that the fame of Arkwright rests, but also on the power of mind displayed in remodelling the habits of people accustomed to desultory working, and, in short, in establishing the factory system.

The next great invention was also produced by a man in humble circumstances,—Samuel Crompton, a weaver at Hall-in-the-wood near Bolton. This ingenious individual, combining the drawing roller of Arkwright with the jenny of Hargreaves, produced a beautiful, though somewhat complex, machine, to which he gave the appropriate name of the *mule-jenny*. In the mule-jenny the drawing rollers are mounted in a stationary frame, and the twisting spindles in a moveable carriage; the rovings are passed through the rollers and attached to the spindles; the rollers and spindles are then made to revolve, and the carriage to recede from the rollers, carrying away and twisting the attenuated rove. When a sufficient quantity of rove has been given out, the motion of the rollers is suddenly stopped and that of the spindles of the carriage increased to nearly double its former velocity, the carriage itself still receding from the rollers, but at about one-half its former speed; thus the greatest extension only takes place as the rove receives twist to enable it to bear it.

These machines were all the offspring of the cotton manufacture; but it may be well supposed that the principle on which they act would soon be adopted in the spinning of wool, flax, and silk. It is not here necessary to trace the different steps through which, by slow degrees, the parts of these machines were brought to suit the peculiarities of other manufactures. We shall, therefore, proceed to the elucidation of the principles of spinning the various textile materials by machinery, observing first, that, to fit these materials for spinning, they are made to undergo several preparatory processes; the effect of which, when well performed, is to separate the fibres, to unravel those which are entangled, and, except in the case of flax, to present the whole mass in a continuous sliver or ribbon of an equal width and density throughout its whole extent. On this sliver the operation of spinning is performed.

If we take hold of a portion of such a sliver with the hands rather farther apart from each other than the average length of the fibres of which it is composed, we shall find that, by the sliding of the fibres on each other, we can extend it a little without breaking it. Suppose then that we thus extend a few successive portions, and lay them together, and combine them by slightly twisting them, so that the torsion shall

Spinning. generate a certain compression among the co-fibres, we shall now find that we are able to extend the mass considerably farther without breaking, and so by continued drawing and twisting we may attenuate the sliver until it become a fine thread. There are two circumstances which limit its extensibility. The first is that state of it when many of the fibres which compose it end together at the same place, and which it is one of the objects of carding, and the purpose of some of the after processes, to prevent. The second is when the friction produced by the twisting becomes so great that the fibres will sooner break than slide on each other.

The operations, then, to be performed by the spinning-machinery, are, to extend the mass of sliver as it comes from the preparatory machines, by repeated operations, or *drawings*, as they are termed, into a narrower and narrower ribbon; to twist this ribbon into a loose thread or *rove*, to enable it to bear greater extension; and, further, to extend this rove to the last degree of attenuation required, twisting it, at the same time, so *hard*, that, when the operation is finished, and the thread perfectly formed, the fibres will sooner break through, than separate, by sliding on each other. All these operations are, however, more or less mixed up with each other in practice. Thus, the carding engines, besides disentangling the fibres, draw the broad sheet of loose filaments into a narrower and more compact sliver; the drawing-frames extend this into a still narrower ribbon; in the roving-frames the drawing still proceeds, and by an additional apparatus the sliver is twisted; and this drawing and twisting are carried on together in the spinning-frame and in the mule-jenny until the completion of the thread.

The manner in which the drawing is effected may be conveniently represented by a figure. Let *aa* in the figure represent a pair of rollers, which are called retaining rollers; let these revolve in the direction of the arrows with a given velocity, and receive between them the sliver *bd*; they will thus impart to it the rate of motion of their own surfaces; let *cc* be another pair of rollers, which are called drawing rollers, revolving with twice the speed of *aa*, and receiving between them the sliver. Imparting to it now their own motion, they will cause it to move forward twice as fast as it is yielded by *aa*, which it can only do by the fibres sliding asunder. If, therefore, a given length of sliver be passed through the roller, it will be drawn out to twice its original length, and its sectional area will be but half of what it was. The drawing rollers have here been supposed to move twice as fast as the retaining rollers, but their relative speed may be in other proportions. Thus the drawing rollers may move three, four, or five times faster than the other pair, and extend the sliver to three, four, or five times its original length. This difference of speed is termed the draught of the machine, and a machine is said to have a draught of two, three, four, five, or six, as the speed of the surface of the drawing rollers is so many times greater than that of the retaining rollers. It is obvious that, to effect the lengthening of the sliver, the distance between the drawing and retaining rollers must be somewhat greater than the average length of the fibres which compose the sliver. For were the distance less than this, the consequence would be disruption of the fibres themselves, from both rollers having hold of the opposite ends of the same fibres at the same time. But the distance may be too great, which would tend to make the fibres separate entirely at the middle point between the rollers, or at least to make the greatest attenuation take place there.

It is obvious, too, that the amount of extension which a single sliver can endure must be small, from the danger of

the ends of many fibres occurring at the same place. Hence there exists a necessity for laying many slivers of the first drawing together, for the second drawing, and many of these again for the third drawing. This laying together of the drawings, which is termed doubling, possesses the advantage of ensuring greater equality in the thread, from the inequalities of the separate drawings contempering each other. The oftener this doubling is repeated, the more compact and equal, or *level*, the thread will be, and the more capable of enduring attenuation from the interspersion of the endings of the fibres.

As an example, in figures, of the effect of the drawing and doubling processes, suppose the velocity of the drawing rollers to that of the retaining rollers, or, in other words, the draught of the machine to be as 5 to 1, let the length of the sliver before drawing be 1, and its density 1; after the drawing we shall have the length increased to 5, and the density diminished to $\frac{1}{5}$. Suppose a doubling consisting of 8 of those new drawings to be put through the rollers, we shall have a new sliver formed, length 25, density $\frac{1}{32}$; and the result of this doubling being repeated four times, the ratios being the same, that is in figures, $\frac{8}{5} \times$

$\frac{8}{5} \times \frac{8}{5} \times \frac{8}{5} = \frac{4096}{625} = 6.5$. will be a length of 625, and a density 6.5; that is to say, there will be 6.5 times as many fibres in the same space as there were originally, and the length will be increased to 625, this length of 625 being made up of 4096 separate slivers, or ends, as they are termed.

Such is the process of drawing without twist, in its simplest form, and as it is applied to cotton, wool, and silk waste. In flax spinning the nature of the material renders a more complicated apparatus necessary. Each fibre of flax, on minute examination, will be found to be made up of a number of smaller parallel filaments bound together. The separation of these bundled filaments is partially effected by the hackling process; but it is evident, that the thread is not capable of its greatest degree of attenuation, until the total separation of the filaments be completed. For this reason, a hackle, which shall separate the filaments, is an essential part of the drawing apparatus for flax; and, in the repeated doublings of the slivers, a succession of machines is used, in which the hackles are gradually finer.

From the length of the fibres of the flax, the rollers require to be at a considerable distance from each other, and the hackles are placed in the interval between them. They are fixed to an endless chain, working over rollers, and their points are made to move through the sliver, with a speed a little greater than that of the retaining rollers. They thus have a double action. Entering the sliver immediately on its emission from the retaining rollers, and moving faster than it does, they split down the bundles of the fibres, and allow the sliver to be extended by the rollers. As they proceed onwards, the action of the drawing-rollers makes the extending sliver move many times faster than the hackles, and, by this means, straightens and lays parallel those fibres which may happen to be doubled, or to lie obliquely in the sliver. This ingenious apparatus is called the Gill, from the name of its inventor.

The process which succeeds these repeated drawings, whether made by the simple rollers or by the gill, is twisting the sliver into a rove. For this purpose, an addition of a bobbin and flyer is made to the drawing machine. The bobbin is made to revolve with such speed, as to wind up the rove as fast as it is yielded by the last pair of rollers, and the flyer with so much additional speed as to give to the sliver the desired twist while moving between the roller and the bobbin. As the diameter of the bobbin



Spinning. is continually increasing by the accumulation of the rove, and as the speed of the rollers remains constant, it is necessary to vary the speed of the bobbin, so that, as it increases in diameter, it may diminish in speed, and wind up the rove at the same rate throughout. The mechanism for effecting this is, in some machines, very complicated.

The next operation is forming the thread from the rove. For this there are two kinds of machines used,—one, the throstle, which is a simplification of Arkwright's spinning-frame, and consists of a set of drawing rollers with bobbins and flyers as in the roving frame; the other is that combination of the drawing rollers with the jenny, which is termed the *mule*. In the roving and throstle frames the twisting apparatus is stationary, and merely twists, and the twisting succeeds the drawing. In the mule the twisting apparatus recedes from the rollers faster than they yield the sliver, and consequently has a drawing as well as a twisting power. In the throstle, the rove being pulled by the bobbin through the flyer, is, while yet tender, subjected to a continual strain. In the mule the rove is only subjected to strain, as it receives twist enough to enable it to bear the strain without injury. The mule, too, by the peculiarity of its mode of action, destroys those inequalities of the rove which result from defects in the drawing, or injury sustained in the roving. To understand how it does so, it is necessary to observe, that, when a thread of unequal thickness is twisted, the fibres which compose the thick parts, forming larger and more oblique spirals than those which compose the small parts of the thread, require a greater force to twist them, and consequently remain soft, while the small parts become comparatively hard twisted. If a considerable length of such a thread were pulled, the fibres of the thick parts would slide upon each other; while those of the smaller parts, being mutually compressed, by their greater degree of torsion would resist the drawing asunder. The drawing would thus take place only in the thick parts; and, as they diminished in size, the twist would gradually become equally diffused. The mule, acting in this manner, with a drawing and twisting power, upon a considerable length of unequally sized, and consequently unequally twisted rove, reduces its inequalities, and renders it level and uniformly twisted throughout.

Having thus endeavoured to make the reader acquainted with the general principles on which these machines act, we shall now proceed to describe the machines themselves. Arkwright's first machine was called the water-twist frame, from having originally been driven by water-power. It consisted of a pair of retaining rollers and a pair of drawing rollers, such as those we have used for the sake of illustration, which effected the extension of the sliver. From the drawing rollers the sliver passed to another pair of rollers, called the delivering rollers, which, moving with the same velocity as the drawing rollers, had no extending power, but merely compressed the sliver and delivered it to the twisting apparatus. This consisted of the bobbin and flyer of the Saxon or flax wheel, improved in respect of the flyer being rendered automatic in spreading the thread on the bobbin, in the manner which will be seen in the descriptions and drawings of the roving and spinning machines; and this automatic action was shortly afterwards, with good effect, transferred from Arkwright's machine to the hand-wheel by a Mr. Antis. Each system of rollers and twisting apparatus in Arkwright's machine was separate, and was driven by a separate system of gearing, and pulleys and bands, rendering the machine, when of great extent, exceedingly complicated. One of the greatest improvements of modern days, is the simplification of the moving parts, by making each roller continuous along the whole length of the machine, and using only one set of driving apparatus at the one or other extremity, and by making the shaft for driving the twisting machinery also

continuous, as will be seen in the drawing of the frame for flax spinning. Spinning.

We have seen that the parts of the machine which perform the operations of drawing and twisting, viz. the rollers, and the bobbin and flyer apparatus, are very simple. The complexity arises, therefore, from the number of parts required to communicate motion to these parts, and to regulate their movements; and the arbitrary nature of the form and arrangements of the parts for communicating motion, causes the great differences which exist in the various spinning machines. In a brief sketch like the present, it is obviously impossible to notice the many beautiful arrangements which, from time to time, have been introduced. In addition to those machines figured in Plates CLXXVII. CLXXVIII. CLXXIX. Art. COTTON MANUFACTURE, we shall present our readers with some of the spinning machines used in the flax manufacture, and also with the latest improvements in the cotton and worsted spinning machines, which we are enabled to do in the most perfect manner, having, through the kindness and liberality of Mr. Smith of Deanston, been furnished with beautiful drawings of the self-actor cotton and woollen mules, of which he is the inventor and patentee.

Referring then to the above-mentioned Plates, we proceed to the description of the machines contained in Plates CCCCLXV. CCCCLXVI. CCCCLXVII. Plate CCCCLXV, fig. 1st, is an end view of the first machine used in the operation of flax spinning, and which is called the spreading machine. A is a board or table, called the spreading table, over the surface of which an endless web moves round rollers at its opposite ends; on this endless web the stricks of flax are spread, and are by it carried forward to the retaining rollers B. As it comes from between these rollers, it is acted on at the opposite side by the gills or moving hackles, which, with their moving apparatus, occupy the space between B and C the drawing rollers; the upper drawing roller C is moved by the friction of the under one, and is called the pressing roller; its surface is usually covered with leather. The pressure is communicated either by a lever and weight, as in the figure, or by a spring and screw. D the delivering rollers. These have no drawing power, and move just so fast as to keep the sliver tight between them and the drawing rollers, and by them the sliver is discharged into the can E, placed to receive it. All these rollers, when seen in front, as in fig. 2, exhibit the appearance of narrow wheels, as, were they made broader than is required for the mere action on the sliver, the flinty surface of the flax would speedily wear them down into channels, while, by being narrow, their whole surface is worn down equally, and funnel-shaped plates are placed in front of the rollers, to guide the sliver properly between them. The whole of the motions are taken from the drawing-roller shaft in the following manner. A belt from the main gearing of the mill works over a fast pulley on the drawing roller-shaft, which has also a corresponding loose pulley to receive the belt when the machine is to be stopped. To avoid complexity, these pulleys are not shewn in the drawings. A pinion *a*, on the end of the drawing roller-shaft, communicates motion through two intermediate stud wheels *b*, *c*, to a pinion *d*, on the end of the shaft which drives the gill apparatus; on the end of the shaft is fixed a small pinion *e*, fig. 3, to drive the under retaining roller B, through a spur-wheel *f*, whose axle carries a small pinion *g*, gearing into another spur wheel *h*, which gears into a spur-wheel *i*, fixed on the roller axle, and the upper retaining roller is driven by the friction of the under one. The pinion on the shaft of the spur-wheel *f*, also drives the inner roller of the spreading table through an intermediate spur-wheel *k*, working into a spur-wheel *l*, fixed on the roller axle. The lower delivering roller has on its end a pinion *m*, which is driven through the intermediate wheel *o* by the pinion *n* fixed

Spinning. on the end of the drawing roller-shaft *o*. From this pinion motion is also conveyed to other three portions of the machinery; first, through the wheels *p q*, to the cleaning roller which is seen at *F* in the figures; this roller is formed of wood covered with listing, which rubs on the surface of the pressing roller, and removes any filaments that may adhere to it; second, through an intermediate wheel and pinion *r*, to a wheel *s*, on the shaft of which a circular brush is fixed, whose purpose is to clean the gills, as is seen in the enlarged representation of that part of the apparatus at fig. 11; and, third, to another pinion *t*, whose shaft carries an endless screw working into the teeth of a small wheel *u*, called the measuring wheel. Its purpose is to give notice to the attendant of the machine, whenever a pre-determined quantity of sliver has passed through the rollers: this it does by a stud fixed on its face coming in contact, at every revolution, with the tail of a lever *v*, whose other end is attached by a wire to the spring of a bell; when the stud, in its progress round, comes in contact with the upper end of the lever, the spring of the bell is drawn from its position, and the moment the stud escapes the lever, the spring is let back with a jerk, which rings the bell. The wheel can be substituted by others containing a greater or lesser number of teeth, according to the length of sliver required.

The only remaining part of the machine to be noticed is, a shaking motion, communicated to the cans while receiving the sliver, that it may be deposited in regular layers. This is best seen in fig. 1. The can is placed on a hinged bracket at *v*, and is steadied by another bracket at *x*, both brackets having semicircular arms, which partly embrace the can; to these brackets, and consequently to the can, a regular jolting motion is communicated as follows. On a rod which passes across the machine a short lever *y* works; on its outer end is hung a weight, and to its other end is attached a rigid rod, connecting it with an eccentric fixed on the drawing roller-shaft. The lever is by this means jolted alternately up and down in every revolution of the drawing roller, and being connected by rods with the brackets *v, x*, they, with their cans, are also moved in the same manner.

Drawing machine.

Flax, after having been passed through the spreading machine, is drawn twice or oftener. The drawing machine is the same as the spreading machine, except in having no spreading table, the sliver being drawn directly from the cans, which are carried from the spreading machine, and placed at the retaining roller end of the drawing machine at *H*, and in having three in place of two retaining rollers. The drawing machine, too, is of a lighter construction than the spreading machine, and its gill teeth are finer.

Figs. 4 and 5 shew the two sides of the machine. *A* is the drawing roller-shaft, and the motion is communicated from it to the other parts as in the spreading machine.

Roving machine.

The roving machine, fig. 6, is similar to the drawing machine, except that it is still lighter in construction, and that in it, in place of the delivering rollers, and the cans to receive the sliver, there is substituted the apparatus for twisting the rove seen detached in fig. 7. When the sliver leaves the drawing rollers of this machine, it is passed through the top part of the spindle, which is tubular, and called the eye of the spindle; it is then conducted by the flyers *K* to the bobbins *L*. The arms of the flyers are usually bent wires, with eyelits at their lower extremity, through which the thread is passed. Here they are represented to be tubular throughout their whole length, this being considered to make a smoother thread. The parts of the machine not already described are, the spindle rail *M*, the coping rail or shifting plate *N*, on which the lower disc of the bobbin rests. The coping rail has an alternating motion up and down through a space equal to the surface of the bobbins on which the threads are spread; and by carrying the bobbin through this space, the thread is spread

equally over its surface. This alternating movement is variously effected. In the machine represented, it is done by a mangle wheel at *O*; but in other machines it is given by a heart wheel acting on the rail through a lever and chain. From the circumstances before described, it is necessary that the rotatory motion of the spindle and bobbin should be, to a certain extent, independent of each other; and, accordingly, while the speed of the spindle remains constant, the speed of the bobbin is made to diminish as its diameter increases by the accumulation of thread. In the ordinary construction of the machine, this differential movement is regulated by the attendant, by the friction of a string which can be made to embrace more or less of the periphery of the bottom disc of the bobbin, as represented in the figure of the spinning machine. The spindle and bobbin are both driven by a band passing over a pulley fixed to them; and while the speed of the spindle remains constant, that of the bobbin is gradually diminished as it fills, by the attendant moving the string successively along into the different teeth of a rack, so as to make it embrace more and more of the surface of the bottom disc, and thus create a friction which retards the speed. Thus the proper working of the machine depends entirely upon the vigilance of its superintendent; and a simple yet accurate differential movement is still a desideratum.

In the machine represented in the plate, the differential movement is exceedingly accurate and beautiful, but is so complex that it would require many detailed drawings, to give the reader a correct idea of it. This motion, and many other improvements in the spinning apparatus, are the invention, we believe, of Mr. Fairbairn of Leeds.

Figs. 8 and 9 are a side and front view of a spinning machine. frame, drawn from a machine constructed by Mr. Russell of Kirkaldy. *AA* is the bobbin rail on which the bobbins from the roving machine are placed; *bb*, the retaining rollers; *cc*, slip rollers for guiding the rove; *dd*, drawing rollers; *e*, the traverse shaft; *f*, the cylinder shaft.

The cylinder shaft is driven from the main gearing. A belt from a pulley on the end of the cylinder shaft gives motion to a pulley, which is called the speed pulley, because all the motions are calculated from it. The speed pulley shaft carries a pinion gearing into a wheel *b*, on the end of the drawing roller shaft, which again, by a train of wheels, communicates motion to the retaining rollers. The spindles are driven by small bands from the cylinders of the cylinder shaft passing over wharves on the spindle shaft; and the differential motion of the bobbin is produced by the friction obtained from a small cord or temper-band, as it is called, embracing more or less of the periphery of the under disc of the bobbin, as before described.

The motion of the heart-wheel, which, through the lever and chain, gives the traverse motion to the bobbin, is taken by wheel and pinion from the retaining roller shaft. The speed of the spindle is from 3200 to 3500 revolutions per minute. The average work of this machine is two hanks of yarn, of average quality, for each spindle in a working day of twelve hours.

The machines for drawing and spinning tow are the same, or nearly the same, as those for spinning flax. From the shortness of the fibre of tow, the drawing and retaining rollers are set much closer together, and the gills are circular.

In the fine spinning of flax, the thread is moistened, by being made to pass through a trough containing water; a practice probably derived from the custom of spinsters moistening the thread with saliva in household spinning. By the modern improvement of the substitution of hot for cold water, a much finer, smoother, and more even thread can be spun from the same quality of flax than before.

The flax-spinning machinery has recently been introduced with great success into the spinning of silk waste,

Spinning.

Spinning machine.

Spinning. which was formerly treated in the same manner as cotton. As the gills are used in the spreading, the drawing, and the roving machines, and as it is in the use of the gills that flax machines differ from the machines for spinning cotton, we have given in figs. 10, 11, and 12, the two kinds in ordinary use.

Fig. 10 shews the common chain gill. A A are the gill rollers; B the gill chain, consisting of a series of links, jointed together at their lower extremity, as is better seen in the separate representation of them at C. There is one of these gill chains at each side of the machine, and they are connected together by the guard bars *dd*, which extend across the machine. The gills are attached to the gill stocks *ee*, which stretch across the machine, and whose ends work through the slit in the links of the gill chain, and extend beyond the links into the slit of the guide frame *f*, of which there is one on each side of the machine. These slits are called the gill slides, and perform the office which we will immediately see. As the gill stocks are carried round by the links of the gill chain, it is evident that they will be elevated or depressed according as the path of the links agrees with the line of the slides. Their path and the slides are so made to agree from *a* to *b*, that the stocks occupy the highest point of the links, and the hackles are protruded to their greatest extent, and work through the sliver in its passage between the retaining and drawing rollers. At the point *b*, the slides suddenly diverge from their former line, and nearly at right angles, by which divergence the gill stocks' ends are suddenly moved from the highest to the lowest point of the link, and the hackles are withdrawn from the sliver nearly at right angles. In following further the course of the guides, it will be seen that the circles of the slides are of the same size as those of the inner ends of the links, and consequently the gills are retained at the inner end of the links until the divergence of the slide at *a* again protrudes the hackles through the sliver in a direction nearly at right angles to its course. When the gills are withdrawn, their points fall just beneath the level of the guard bars which sustain the sliver, and in the case of entanglement, prevent it from being drawn down along with the gills.

Such is the common flax gill; and its defects are, first, that the teeth of the gills cannot be made to approach close enough to the drawing rollers, or to enter the sliver immediately after leaving the retaining rollers; and, second, that they do not leave and enter the sliver at right angles to its course. To remedy these defects, the screw gill has been introduced. Of this a longitudinal section is given at fig. 11, and a transverse section at fig. 12. *aa, aa*, are four screws; the two upper screws have their threads lying in the reverse directions of the under ones; *bb* are the gill bars, stretching across between the opposite pairs of screws, and having their ends working in the screw threads. When the upper screws are moved round their axis, the gill bars are carried forward through the sliver, being supported in their position by the bracket pieces *cc*, under the screws. These bracket pieces and the threads of the screw terminate, just at the drawing roller, so that when the gill bar has arrived at that point, it is no longer supported by the bracket, and falls down to a lower bracket *dd*, which guides it in the same manner for the under screws. In its fall the gill bar is aided by a cam on the screw-shaft striking it when it has reached the termination of the screw, and it is guided in its descent, and pressed into the thread of the lower screw, by a strap of iron forced against it by a lever. The threads of the lower screws are so arranged as to carry the gills along on its bracket piece towards the retaining rollers, and when it has reached the termination of the screw, a cam on the screw-shaft, with a guiding apparatus as before, raises the gill again to the upper bracket, to be acted on again by the upper screws.

As an introduction to the description of Mr. Smith's self-

acting mule, it is necessary to give the reader a general idea of the hand-mule jenny, a representation of which will be found at Plate CLXXVIII, fig. 12. By consulting that figure, the reader will see that the mule consists of two distinct parts; first, the beam at the right hand of the figure carrying the drawing rollers; and, second, the carriage upon which the spindles are mounted for the purpose of giving twist, the beam being stationary, and the carriage capable of moving upon iron races along the extent of the machine, as may be seen by the dotted lines on the figure. Motion is communicated to the different parts by mechanism, mounted on a frame-work placed across the mule, either at one end or in the centre. This frame-work, with its apparatus, is called the headstock.

When the mule is put in motion to perform the operation of spinning, the rollers are moved by wheel-work from the headstock, and the carriage is gradually moved outwards, keeping pace with the delivery of the rollers; and while this process is going on, the spindles are put into a rapid motion by belts and bands proceeding from the fly-wheel of the headstock, and which can be adjusted to give such an amount of twist as may be necessary. The whole of the twist may be thrown in during the outcoming of the carriage, as is generally done in spinning wefts, or as in twist-spinning, when part is thrown in during the slubbing, and the remainder after the carriage has reached its limit, and the rollers have stopped. In the outward movement of the carriage, the mule is driven by power communicated from the main gear to the fly-wheel shaft of the headstock, by a belt with a fast pulley, and when the stretch or draw has been completed, the machine is entirely stopped, by the belt being thrown on a loose pulley adjoining. The spinner then lays hold of the fly-wheel with one hand, and turns it back so far as to throw off all the coils from the stems of the spindles, which is technically called *backing off*, while with the other hand he puts down the faller or guide to the proper position for winding the threads on the copes. He then pushes the carriage towards the beam, directing the faller with one hand, so as to guide the threads in proper form on the cope, while with the other hand he turns forward the fly-wheel with such force, as to cause the threads to be wound upon the copes with a uniform and proper tension. When the carriage has arrived at the beam, he lifts up the faller wire, so as to throw the threads in coils from the copes to the points of the spindles, thus completing the draw or stretch, as it is called, and leaving the whole in proper order to commence a new draw. The driving belt being then thrown on the fast pulley, the machine is again put in motion, and so goes on successively.

All these motions are in Mr. Smith's machines performed at the proper instant by the machines themselves. Plate 466 fig. 1, shews a side elevation of the headstock, and an end elevation of the carriage. Fig. 2 is a bird's eye view of the carriage, race-rods, &c. The other figures in the same plate exhibit details of the mechanism, which will be referred to in their proper place.

The same letters refer to the same parts in all the figures. A A A A is the framing of the headstock, B the beam upon which the rollers are mounted, C the race-rods upon which the carriage runs, D the frame-work of the ends of the carriage, E the wooden rails of the carriage.

The motion of all the parts of the machine is derived by belts and pulleys from the driving shaft F, which is itself driven by a belt from the main gearing acting on its fast pulley G, and when it is necessary to stop the whole machine, the belt is thrown on the loose pulley H. The driving shaft carries two pulleys; a belt from the larger one I drives the pulley K of the speed-shaft T, and a belt from the smaller one L drives the pulley of the change-shaft M. These two shafts also carry loose pulleys, on which the belts are thrown at the proper instant for stopping the motion of the shafts,

Spinning.
Cotton
mule-jenny.

Smith's
self-acting
cotton
mule-jenny.

Spinning. by levers and apparatus whose action will be better described while noticing the action of the machine.

The regular outward motion of the carriage, its time of rest when at its outward limit, to allow time for the twisting of the threads, and its rapid inward motion during the winding of the threads on the copes, is obtained from the change-shaft N in the following manner. The near end of the change-shaft carries a pinion O, which, through the wheels *abc*, drives the shaft *c*. The shaft *c* is carried in the lower, and the shaft of the wheel *p* in the upper socket of a frame, called the vibrating frame, from its having a vibrating motion, by its axis turning in bearings *dd*. The further end of the shaft *c* carries a pinion of eight, nine, or more leaves, which works into the teeth of a peculiarly formed wheel P, called the regulating wheel; and it is this wheel, by the motion derived from its singular line of teeth, which effects the varied movements of the carriage, by the spur-wheel *e* attached to it working into the teeth of the carriage-rack Q Q. When the pinion is working into the outer ring of the teeth, which, it will be observed, are reversed, the regulating wheel and its spur-wheel move in a regular manner, and roll the carriage outward. When the carriage has arrived at its outward limit, the pinion will have begun to act on those teeth of the wheel which are eccentric, and which, lying nearly in the direction of a radius of the wheel, cannot give it rotatory motion; it therefore stops, and the carriage of course is also stationary, while the pinion, rolling along the radial line of teeth, forces the vibrating frame, which carries its shaft, to vibrate round its axis, to enable the pinion to approach nearer to the centre of the regulating wheel. When it arrives at that part where the teeth begin to get concentric, it again puts the regulating wheel in motion, but in an opposite direction to its former motion, for the teeth are now outward. This causes the inward movement of the carriage, which is much more rapid than its outward movement, from the smallness of the circle of teeth. When the carriage, in its inward motion, has nearly reached the drawing rollers, the pinion will have begun to work into the opposite eccentric line of teeth; this, as before, will be followed by a reverse vibration of the frame, and the simultaneous stopping of the regulating wheel, until the pinion have again arrived at the reversed teeth of the outer circle, when the same series of movements is again ready to take place, and these changes in the motion of the carriage are, by the peculiar form of the line of teeth, made in the most gentle manner. It is necessary that the carriage maintain perfect parallelism with the line of the drawing rollers throughout its course; nor will this appear to be easily effected, when we consider that it is sometimes fifty or sixty feet long, and that the force for moving it is applied either at one end or at the middle of its length. This parallelism of the carriage, which is technically called *squaring*, is effected in hand-mules by means of bands, called *squaring bands*; but in this machine it is effected in the following manner. A long shaft or cylinder *ff*, which, for the sake of lightness, is constructed of iron or tin-plate, passes along the whole length of the carriage, and carries upon it at each end, and sometimes, in long carriages, in the middle also, toothed wheels *g g*, which, working into racks *hh*, attached to the races or railroad on which the carriage runs, insure perfect parallelism in its movements.

From the spur-wheel *e*, attached to the regulating wheel, the motion of the drawing rollers R is derived through the wheels *ikl*; but as the motion of the rollers is only in one direction, and continues only during the outward motion of the carriage, while the regulating wheel has a forward and backward motion, there is required a means of disconnecting them, when it is necessary that the rollers should stop. Accordingly, the wheel *k*, through which the roller shaft *b* is driven, runs loose on that shaft, but has within it a ratchet

wheel fixed to the shaft, and the pauls of the ratchet are attached to the wheel *k*. Hence it follows, that when the spur-wheel is driven in that direction in which the pauls will slip over the ratchet, the ratchet-wheel, and consequently the shaft *l*, and the rollers, will remain stationary, and this they do while the regulating wheel is performing its backward motion; but when the regulating wheel is moving in the opposite direction, the pauls of the spur-wheel catch on the ratchet-wheel, and give motion to it and to the rollers.

Having thus described the manner in which the motion of the carriage and rollers is effected, we will now show how the twisting and winding-on motion is communicated to the spindles of the carriage. The speed-shaft K, we have seen, is driven directly from the driving-shaft pulley I; from the pulley R of the speed-shaft a band proceeds and passes over the stud pulley in the frame at R', and over the guide pulleys of the carriage at S, and thence to the drums 43, which act on the spindles in the usual way; by this a uniform revolving motion is communicated to the spindles, while the carriage is running out, and during its pause at the end of the course. The speed-shaft must then be stopped, that the *backing off* may take place, and while the carriage continues its inward motion, as, although the speed-shaft moves and drives the spindles during this inward motion, for the purpose of winding on the thread, yet the winding-on motion being variable in speed, and the speed of the shaft being constant when driven by the driving-shaft pulley, it is necessary for winding on, to drive it by some other means. Accordingly, an apparatus is provided, which at this juncture throws the driving belt of the speed-shaft upon its loose pulley, and at the same time lets fall a break *m* upon a break pulley fixed upon the shaft, and thus allows the new moving parts or winding-on apparatus to come into play. The break is attached to the short end of a lever *n*, to the upper part of whose long end a spiral spring is attached. The action of the spring tends constantly to force the breaks upon the pulley, but it is restrained by a catch which is withdrawn at the proper moment by the action of an apparatus to be afterwards described; and when the winding on is completed, the break is withdrawn from the pulley, and the break lever again put on its catch, by the action of a cam fixed to the under socket of the vibrating frame pressing down the lever friction-pulley, as is better seen in detached fig. 3. To communicate the winding-on motion to the speed-shaft, when its twisting motion is stopped, there are three or more pauls *o*, attached within the rim of the break pulley, which, when the speed shaft is at rest, fall into a ratchet-wheel *o'*, to which is attached a spur-wheel *p*, fitted loose upon the shaft; but when the speed shaft is in full motion, the pauls, by the action of the centrifugal force, are thrown out of the ratchet-wheel, which, with the spur-wheel, may thus remain at rest, or be driven at any slower or quicker rate by the spur wheel *q* of the winding-on shaft *r*, which derives its motion from the roller shaft *t*, through the spur-wheels *s*, *r'*, and it is plain that when the belt of the speed-shaft T is thrown on the loose pulley, causing the shaft to stop, and the pauls of the break pulley to fall into the ratchet-wheel *o'*, then the motion transmitted from the roller shaft to the spur-wheel *p*, to which the ratchet-wheel *o'* is attached, will be by it communicated to the speed shaft T. The motion thus transmitted from the roller shaft *t*, which is itself moved by the regulating wheel P, to the spindles, is capable of adjustment by a peculiar mechanism, so that the motion of the spindles, and the degree of tension which the threads undergo in winding on, may be modified in the degree required. This elegant differential movement, carried by the shaft *r*, is seen at fig. 4. An arm 1 is carried by the shaft *r*, from which a stud 2 projects, carrying a pinion 3; this pinion on the one side gears into a series of inverted teeth, extending round near the periphery

Spinning. of the friction pulley t , and on the other into a series of external teeth 4; the pulley t , and the wheel 4, are both fitted loose on the shaft r ; when the shaft r , with its arm 58, move round, the pinion being in gear both with the teeth of the pulley t , and the wheel 4, has a tendency to carry both of them in rotation with it; but if either of them be held fast, it is evident that the motion of the pinion will communicate so much additional motion to that which is loose, by acquiring from the stationary wheel a motion round its own centre, as well as its motion round the shaft. In this way, whatever part of the motion of the one is restrained, will be imparted to the other. This restraint is imparted to the pulley t , by a band or strap passing round it in its groove. The band is of cotton thread, made fast at one end to a stud t , projecting from the frame, and passed round the pulley and carried along to the opposite end of the headstock, where it is attached to the cross-tail $t' t'$ of the lever u ; and the degree of tension communicated to the friction-band can be modified within certain limits, by the lever u having a moveable weight u' adjustable in any position by means of the pinching screw. When the threads are winding upon the bare stems of the spindles, at the beginning of a new set of copes, and for a few stretches after the commencement, it is necessary to increase the motion of the spindles suddenly at the beginning of each winding on, until the bottom of the cope has acquired some volume. For this purpose an additional pressure is applied to the lever v , through the connecting rod proceeding from the lever w , upon the lower surface of which pressure is thrown by a simple apparatus connected with the building bar of the carriage, to be afterwards described.

The mode by which the amount of twist is regulated, is as follows. On the outer end of the driving shaft F , there is an endless screw F , working into a screw-wheel X , on the end of an upright shaft. The number of teeth on the screw-wheel is so regulated, as to cause it to perform one revolution during the time when the twist is throwing into the threads, after the carriage has reached its limits at the head; and it stops the twist by a cam X' , on its upright shaft acting on the levers, which throw the belts from the fast to the loose pulley of the speed-shaft.

The next thing to be considered is the apparatus attached to the carriage for *backing off*, and for building the threads regularly on the copes during the winding on. When the carriage has arrived at the utmost limit of its outward stretch, and the spindles have been stopped by the break, then before the faller wire can be put down to guide the threads upon the spindles, the operation of *backing off* or unwinding the spiral coils of thread from the spindles, takes place. The usual mode of effecting this, is by causing the spindle to make three or four backward revolutions; but a more simple mode is here adopted. An under faller shaft U , with its arms and wire, stretches along the whole length of the carriage, and is placed behind the building faller shaft V ; but its arms are so much longer, that its wire is in front of the building wire, and the wire is kept in such a position, while the carriage is coming out, as to be at about a quarter of an inch distance below the threads, and by being raised at the proper moment, it strips the spiral coils from off the spindles. To the further end of the under faller shaft, there is attached a lever y , carrying an adjustable nut to the lower part of which the upper part of a spiral spring is attached by a hook, and its lower end to the framework below. The effect of the spring is to draw down the lever, and consequently to raise the under faller wire. This is however counteracted until the proper moment for stripping off the coils, by a projecting lever z at the other end of the under faller shaft, being held down by a moveable rod z' : the upper end of the rod is attached to the lever z by a stud bolt passing through an opening in the arc head of the lever, and its lower end rests on an inclined plane, forming

part of the building-on apparatus to be afterwards described. On the rod there is an adjustable stud, made fast by a pinching screw, which, resting on the top of a lever W , prevents the spring from drawing up the under faller. When this lever is turned round its fulcrum, in the manner we shall afterwards see, it allows the rod to fall, and the under faller consequently to rise, and the faller is again depressed at the proper instant, by the inclined plane z'' attached to the building-on apparatus, which we shall afterwards describe, raising the rod into its original position, in which it is again retained by the lever W . From the near end of the building wire shaft V there projects a toothed arc 5, gearing into a vertical rack 6. This rack has a small projection on the back, to which is jointed the folding arm 7, whose opposite end is jointed to the folding leg 8. The lower extremity of the folding leg carries a friction pulley, which rests on the upper surface of the curved piece 9; and it also carries a T-headed nut, which works in a vertical groove on the spur piece 10 attached to the carriage, and so guides the lower end of the folding leg in a vertical line, while it is moved up and down by the action of the curved piece. If the bent arm and leg be drawn into the same straight line, while the friction pulley of the leg remains in its position, the rack to which the upper joint of the arm is attached will move up, and acting upon the toothed rack of the building wire shaft, will turn that shaft round, and depress the wire; and the depression of the wire will be greater or less, as the foot of the folding leg is at a higher or lower point of its vertical slit. To force the folding leg and arm into the same straight line, the following apparatus is employed. A sliding bar X called the poker, resting upon a bearing at 11, is attached by a joint to the connecting arm 12, whose other end is attached by a joint to the folding leg. When the carriage is nearly at the limit of its backward motion, the end of the poker to which the arm 12 is attached, catches against, and is retained by the end of the lever 13, while the carriage runs back to its full stretch. The poker is thus sent home, and as a consequence, carries with it the arm 12, and the jointed leg and arm 8 and 7; and it carries these a little beyond the vertical position or line of centres, from which they are again disengaged, and fall into the position represented in the drawing, when the carriage, having arrived nearly at the limit of its inward course, causes the adjustable nut at the other end of the poker to strike against the bracket piece Y of the frame. In considering the next apparatus described, we shall show that the point upon which the folding leg rests, is subject to being raised and lowered, and consequently the sliding bar is also raised and lowered; the effect of which is to make the nut at the end of the poker strike on different vertical points of the restraining bracket Y ; so that by making the surface of this bracket upon which the points strike to lie in an oblique direction, the exact period of liberating the jointed leg and the building faller can be regulated with precision. Thus, when the building takes place at the bottom of the spindles, the faller is made to be liberated sooner than when the building approaches nearer to the point, and by this means the due tension of the thread is preserved at the lifting of the faller. A palm from the arm 12, reaches to the supporting lever W of the under faller, and carries a stud which works through the curved slit in the tail of the lever, and retains it in its position; and a small spiral spring, seen in the drawing, being attached to the end of the palm, and to a pin upon the folding leg, serves to keep the arm 12 in its place. From this arrangement it follows, that as the lower end of the folding leg is moved up in its vertical slit, it will carry the stud of the palm nearer to the fulcrum of the lever W ; and that when the jointed arm and leg are brought into the same straight line, the stud of the palm will force the lever W round its fulcrum more or less quickly, as the stud of the palm is at a greater or less dis-

Spinning. tance from the lever's fulcrum, or, what is the same thing, as the lower end of the folding leg is more or less elevated in its vertical slit.

The form of the copes when finished is conical; and to build the thread in this form, it is necessary that the building wire should at first have a very limited range of motion, guiding the thread over that part of the bobbin alone where the body or thickest part of the cope is to be, and gradually extending the surface on which the thread is to be deposited at every successive layer, until the cope be completed. To effect this, it is necessary that the apparatus of the jointed rods which we have described, should first have a very limited range of motion. The friction pulley at the foot of the rod, rests, as has been said, on the curved surface of the piece 9. This piece turns on a joint in the building frame at 14, and has a tongue 15, passing down to a pin 16, which moves in a horizontal slit in the headpiece 17. This pin projects from the frame, and carries a nut 16, through which a screw, held in bearings in the headpiece 17, works. On the end of the screw there is a ratchet-wheel 18, which is moved round a tooth at every traverse of the carriage, by the lever of its paul being acted upon by an inclined plane 19, attached to the carriage; and thus the screw carries the nut 16 and its pin along the slit in the headpiece, under the end of the tongue of the curved piece 15. A diagonal bar 20 in the building frame rests also upon the nut pin. The lower surface of this diagonal bar is nearly a straight line. As the pin moves along under this surface, the building frame 21 is allowed to drop gradually in proportion to the obliquity of the diagonal; but as the surface of the tongue 15, which rests on the pin, forms an angle with the line of the plane of the diagonal, so the tongue-piece, and the curved surface-piece to which it is attached, will be allowed to drop more than the building frame, as the nut passes along; and the curved surface will thus be more and more declined from the horizontal position, thereby allowing a greater vertical movement of the folding leg at each successive draw, the effect of which will be to increase the range of the falling wire, and consequently to give the body of the copes a longer form. When the pin has been carried to a certain point, it escapes the tongue-piece, and proceeds along the surface of the diagonal only, which being straight, and at a regular inclination, allows the building frame to fall down through equal spaces at each successive draw, producing also equal increase on the range of motion of the falling wire. When a set of copes has been completed, the pin is wound back by the winch attached to the end of the screw. The whole of this apparatus is attached to a sliding bar 22, working on studs fixed to the frame of the carriage, and having at its further end a rack, into which a pinion, attached to a wheel on the axis of the carriage, works. This wheel moving in unison with the carriage, by means of the pinion and rack, causes the sliding bar to perform a traverse of six inches at each draw. The curved piece 9 is thus moved under the friction pulley at the foot of the folding leg, and forces it to move in its vertical slit, to the extent regulated by the screw apparatus which we have just described. To this building apparatus is attached the simple addition before alluded to, for throwing an additional pressure on the lever *v*. It consists of a small lever 23, jointed at 24, and having a nose-piece on its opposite end resting upon the nut pin 16. From the nose-piece end there projects a pin, 25, at right angles, which, when the carriage is at its outward limit, passes along the under surface of the lever *o*, and by means of the rod connecting this rod with the lever *U*, throws an additional tension upon the tension-band; and as the nut 16, by the action of the ratchet-wheel, is drawn back, it relieves the nose-piece of the lever, which falls down into the position shown in the drawing, and its pin ceases to act on the lever *o*, until one set of the copes being finished, the nut and pin 16 are again brought forward

by the screw and winch, and raise the nose-piece, ready to commence a new set of copes. The apparatus which forces the poker home is the spinner lever 13, whose inner end is attached by a universal joint to one end of another lever, 26, the other end of which is attached to the bottom of the vibrating frame. When the regulating wheel ceases to move, the vibrating frame vibrates nearer to its centre, and by means of the lever 26, moves the outer end of the spinner lever toward the carriage, which is at that time nearly at the limit of its outward course; and the lever thus lays hold of a projecting piece on the end of the poker before alluded to, and so slides it home.

Leaving the minor parts to be incidentally noticed, we shall proceed to describe the general action of the machine during the completion of a stretch or draw. The carriage being at the roller beams, the machine is put in motion; and the pinion working in the outer teeth of the regulating wheel, brings out the carriage with a slow and uniform motion, while the rollers move in exact unison, and the speed shaft is in full motion to give twist to the thread, as the slubbing is given out by the rollers. When the carriage is nearly at its utmost limit, a finger piece 27, attached to the pulley bearer of the carriage *S*, comes in contact with the tail of a hanging lever 28, which is connected by a wire 29, to a cross-tail 30, on the bottom of the axis of the lever. This causes the lever 31 to move round its fulcrum, and throw the driving belt of the pinion shaft from the fast pulley *M* to the loose pulley *M'*, whereby the movement of the regulating wheel, and all the movements taken from it, are stopped; but the speed-shaft *T* being driven directly from the main-shaft, continues to revolve. When the proper quantity of twist at the head has been given, the cam *x* will have arrived at the point of the lever 32, and pushing it round upon its fulcrum, will cause its opposite end 33, to draw the wire 34, attached to the guide lever 35. This shifts the belt from the fast pulley *K*, of the speed-shaft *T*, on to the loose pulley *K'*; and the cam immediately moves the lever 36, which, through the medium of the wire 37, draws off the break lever-catch 38, and allows the break to fall down upon the break pulley, and stop the movement of the speed-shaft and spindles. At the same instant, the cam *x'* having reached the adjusting point of the lever 31, moves this lever, and throws the belt again upon the fast pulley of the change-shaft. Thus the shaft is again in motion, and its pinion travelling down the radial series of teeth of the regulating wheel, causes the vibrating frame to vibrate towards the centre of the wheel. The cam on the bottom of the vibrating frame, in its progress, passes over the friction pulley of the break lever, and relieves the break; and at the same time the spinner lever, which is attached by its rod 26, to the bottom of the vibrating frame, turns round its fulcrum, and shoves forward the sliding bar or poker, thereby relieving in the first instance the under faller, which immediately rises and strips the coils, and the continued motion of the spinner lever and sliding bar forces up the folding leg into its vertical position, and consequently forces the building wire into its building position. When this movement is about to be completed, the pinion of the regulating wheel has arrived at that part when the motion of the wheel begins to be reversed, and the carriage begins gradually to move inwards. At this instant, the winding-on motion, which is taken from the regulating wheel, begins to act, and the movement of the carriage and winding-on continue to operate, until the carriage has reached its inward limit at the beam. The adjustable pin at the end of the poker then comes in contact with the bracket piece *Y* of the framework, and relieves the building faller; and a projecting finger 38, attached to the upper bearer of the guide-pulley of the carriage, comes in contact at 39, with the cross lever of the belt guide 35, and throws the belt again on the fast-pulley of the speed-shaft, and the

Spinning. machine is again in order to commence another stretch or draw.

Smith's
self-acting
woollen
mule.

Of Smith's self-acting woollen mule, several parts are the same as those of the machine already described. To these we merely refer, reserving for particular description such parts as are peculiar. Fig. 1 is a side elevation; fig. 2 bird's eye view; the other figures represent detached portions of the mechanism. A A A is the general framework of the headstock, B B B the general framework of the carriage, C the main driving pulley, C' the corresponding loose pulley, D the driving shaft, which in this case lies along the framework, E E' bevel wheels, through which motion is communicated from the driving-shaft to the shaft E', called the fly-wheel shaft, on which the drum F, and the fly-wheel G, are fixed. The drum F by a belt communicates motion to the driving-shaft H, through its fast pulley H²; H' is the corresponding loose pulley; I is a pinion upon the near end of the driving-shaft, which communicates motion through the wheels I¹ and I², to the stud wheel K, on the central shaft K', of the vibrating frame L. From the wheel K motion is communicated to the wheel M, of the vibrating shaft M'. Upon the opposite end of this shaft the mangle pinion N' is fixed. This pinion drives the mangle or regulating wheel N, as described in the former machine. The mangle wheel in this machine moves the carriage rack by the eccentric wheel O, fixed on the end of its shaft gearing into the other eccentric wheel O', whose shaft carries a spur-wheel P, which gears into the carriage rack P' P'. Round the periphery of the mangle wheel are external teeth, which, through the stud wheel Q, drive the pinion Q', fixed upon a small cross shaft R, called the roller shaft. Near the opposite extremity of this roller shaft there is fixed a disc R', working in the bosom of the toothed wheel S: this disc carries pauls, which work on a ratchet-wheel, fixed also in the bosom of the wheel S. The wheel S being loose upon the shaft, is allowed to remain at rest, when the disc moves in such a direction that the pauls slip over the teeth of the ratchet. The wheel S gears into the stud wheel T, which again gears into the wheel U, upon the end of the rollers U'. The stud-wheel T moves upon a stud carried by the radial lever T', whereby it is permitted to move out and in of gear with the wheel S. These movements are regulated by the disc lever V, which, resting with its outer end on a disc pulley on the end of the wiper pulley X, raises and depresses the point of the radial lever T', by the movement of the mangle wheel shaft. The place of the wiper on the face of the disc X, can be shifted to adjust the point of movement. The roller shaft R carries another wheel a, which, through the intermediate wheel a', drives the wheel b' fixed on the differential shaft b. This shaft carries the differential box c, which is the same as in the former machine, and through which motion is communicated to the twist shaft d, by its wheel e, for winding-on: its pulley is restrained by a band and lever, as in the former machine. f is the break pulley on the shaft d, with its ratchet-wheel f', acting as described in the former machine. The manner in which the break is pressed on the pulley in this case, is seen in the detached drawing, fig. 3. Returning to the driving shaft H, there is a pulley g running loose upon the shaft for raising the driving belt. Its nave carries a series of small pullies of different diameters, for communicating motion to the cross shaft h, which carries a corresponding inversed series of pullies h', by which a considerable difference of speed can at any time be attained. The outer end of the shaft h carries a small pinion i, which, through the intermediate stud-wheel j, drives the wheel j', running loose upon the driving shaft H, but which, by means of a disc k, with a set of catches and a ratchet-wheel, as in the case of the wheel S, can be made fast to the driving shaft. By this means, when the belt is thrown upon the loose pulley g, motion is communi-

cated by the pulleys fixed on its nave to the pulleys h', and consequently to the shaft h, which, again, acting by its pinion i on the wheels j j', communicates a very slow movement to the driving shaft, and through it to the vibrating frame pinion, which works in the mangle wheel, which is necessary for regulating the back movement of the carriage, while the twist is throwing into the yarn; and its speed can be easily and quickly modified to suit any grist of yarn, by shifting the band upon the grooved pullies g, h'. The amount of twist is regulated, as in the former machine, by the worm screw l, upon the main driving-shaft D, working into the crown wheel l'. The shaft of this wheel carries on its lower end the wheel m, which is called the change wheel, because its place may be substituted by wheels of various numbers of teeth, to suit the amount of twist due to the grist and hardness of the yarns to be spun. This wheel, through the intermediate wheel m', drives wheel n on the top of the cam shaft n, upon which are placed the cams or wipers for moving the levers. On the lower part of the cam shaft there is a bevel wheel o, working into a corresponding wheel on the cross shaft p, called the stripping shaft. This shaft carries a radial wiper p', which, as the shaft revolves, comes at a particular point in its course to press upon the lever q, which, being suspended and acted upon by the spiral spring q', is retracted to its former position, when the wiper p' has raised it. The point of this lever operates upon the horizontal plane r, which is made to extend to a length exceeding the greatest distance that the carriage requires to be removed backwards during the throwing of the twist, so that the stripping wiper q may always press upon some part of the plane.

On the inner end of the twist shaft d there is fixed the pulley s, to drive the cylinder pulley of the carriage s'. The band having been wrapped nearly round the pulley s, has its one end passed over one of the stud pullies t, at the right-hand side of the framing, and carried from it over the cylinder pulley s', while its other end is passed round the other pulley t', and thence over the tightening pulley t². The tightening pulley t² moves on a stud, which can be slid along the horizontal slit in the projecting part of the framework, so as to slacken or tighten the cylinder band. Having noticed the principal parts of the headstock, we proceed to the description of the carriage. The frame of the carriage is indicated by B B B B. 1, is the driving pulley, 2, the upper faller rod with its fingers and guide-wires. The apparatus for moving the building fallers is the same as that already described for the former machine. But the stripping-faller apparatus is somewhat different. Two radial sockets 3, project from the under faller-rod 4, near each end; and in these are fitted a running-nut, which can be adjusted to any required extent of leverage, by turning round the screw; and at the lower side of each nut there is a hook, to which the spiral springs 5, are attached, their lower ends being attached to the framework of the carriage. The springs are so adjusted, that they tend to pull round the under faller-rod, which raises the faller-wire with a due force of tension. A radial lever 6, extends from the one end of the under faller-rod, and has an adjustable stud 7, to which a rod 8, is fixed. This rod terminates at its lower end in a socket with a friction-pulley, which, coming upon the inclined plane at the side of the race-road, shoves the under faller to its resting position, when the carriage goes up to the rollers. The end of the stud 9, projects beyond the socket of the upright rod, and rests upon a moveable tappit or sector 10, which is thus turned upon its centre, by the movement of the radial lever 6, attached to the folding-leg, when the poker is moved to put down the upper faller. By this escapement, through the movement of the tappit, the spiral springs are permitted to pull up the under faller-wire with considerable force, by which the coils

Spinning. of yarn, which surround the stems of the spindles during the process of giving the twist, are stripped off or uncoiled, to permit the building-faller to press down the threads to the proper point for commencing the build at each successive stretch.

We now proceed to shew the manner in which the different parts of the machine come successively into action during one stretch or draw. The carriage being supposed at the beam, the fly-wheel shaft is put in motion; and the belts from the fly-wheel and drum of that shaft being upon the respective fast pulleys of the shafts which they drive, the various gear work connected with those shafts is put in motion, and, consequently, twist is thrown into the thread by the spindles, while the rollers slowly yield the slubbing or sliver, and the regulating wheel, with its eccentrics, moves back the carriage, with a motion equivalent at first to the out-give of the sliver by the rollers, but gradually increasing, so as to take up the extension of the sliver, which is caused by the throwing out of the twist. When a sufficient quantity of slubbing has been given out, the cam disc upon the outer end of the mangle wheel shaft allows the roller lever to drop towards its centre, which, disengaging the intermediate wheel that conveys motion to the rollers, instantly stops them; but the twist continues to be thrown uniformly in, and the outward motion of the carriage continues gradually extending the thread, and proportionally diminishing its grist, in the manner regulated by the eccentric wheels, that is, with a motion at first about equal to the delivery of the rollers, and gradually becoming slower and slower. When the carriage approaches its utmost limit outward, the cam piece 11 attached to it, comes in contact with the tail of the hanging lever 12, which, being connected by a wire with a stud in the opposite end of the driving-belt lever 13, shifts the belt from the fast pulley to the pulley 9, giving the slow motion to the vibrating shaft which we have already noticed, which, as its pinion has passed the returning point, moves the mangle wheel backwards, and, of course, the carriage towards the beam, with a very slow and steady motion, giving in to the tension of the threads as the twist is thrown in. As soon as the desired amount of twist has been given, the cam of the cam shaft will come in contact with the escapement lever 14, attached to the bracket 15, and allow the weight to pull the belt lever one notch, throwing the belt upon the loose pulley 9², whereby the movements derived from this shaft cease. Simultaneous with this, one of the wipers of the cam shaft pulls the twist belt lever, so as to disengage the twist shaft; and another wiper acts upon the apparatus, which presses the break against the break pulley, and stops the motion of the spindles. The motion of the cam shaft now causes the wiper of the stripping shaft to press upon the stripping lever, the point of which, pressing upon the cross head or horizontal plane, strips the coils of yarn from the spindles, and puts down the upper faller-wire into a proper position for guiding the threads upon the copes. As soon as this has been performed, one of the wipers of the cam shaft will have arrived at a position to draw off the last notch of the escapement lever, whereby the driving belt is thrown upon the fast pulley of the driving shaft, which with its connections are again put in motion. The pinion of the mangle wheel, now passing along the teeth of the inner range, produces an accelerated motion of the carriage toward the beam; and the winding-on motion is at the same time communicated through the differential box to the twist-shaft and spindles. When the carriage is nearly at its inward limit, a tappit lever, at the point of the vibrating frame, comes in contact with the cross-tail of the twist-belt lever, and throws that belt upon the fast pulley, to put the spindles again in motion for twisting; and at the same instant the mangle pin-

ion has arrived at that point of its eccentric path, at which it takes in to the inverted teeth, and produces the outward motion of the carriage, and the whole train of motions consequent upon it. (B. S.)

SPINOZA, BENEDICT, was born at Amsterdam the 24th November 1632. His father was a Jew of Portugal, and by profession a merchant. After being taught Latin by a physician, the son applied himself for many years to the study of theology, and afterwards devoted himself entirely to philosophy. He began very early to be dissatisfied with the Jewish religion; and as his temper was open, he did not conceal his doubts from the synagogue. The Jews, it is said, offered to tolerate his infidelity, and even promised him a pension of a thousand dollars per annum, if he would remain in their society, and continue outwardly to practise their ceremonies. But if this offer was really made, he rejected it, perhaps from his aversion to hypocrisy, or rather because he could not endure the restraint which it would have imposed. He also refused being constituted heir to an independent fortune, to the prejudice of the natural claimants; and he learned the art of polishing glass for spectacles, that he might be enabled to maintain himself by the labour of his own hands.

His retreat from the synagogue was hastened by an alarming incident. As he was returning home one evening from the theatre, he was stabbed by a Jew: the wound was slight, but the attempt naturally led Spinoza to conclude that the Jews had formed the design of assassinating him. After leaving the synagogue he professedly became a Christian, and frequented the churches of the Lutherans and Calvinists. He now devoted himself more than ever to his favourite philosophical speculations; and finding himself frequently interrupted by the visits of his friends, he left Amsterdam, and settled at the Hague, where he often continued for three months together without ever stirring from his lodging. During his residence in that city, his hostess, who was a Lutheran, asked him one day if she could be saved while she continued in her religion? "Yes," replied Spinoza, "provided you join to your religion a peaceable and virtuous life." From this answer, it has been concluded, that he was a Christian in appearance only, while in reality he regarded all religions as indifferent. But this conclusion would be too severe, even if the woman had been a Mahomedan. His "*Tractatus theologico-politicus*" (Hamb. 1670, 4to.) is a better proof of his insincerity than a thousand such conclusions; for this book contains all those doctrines in embryo which were afterwards unfolded in his posthumous works, and which are generally considered as a system of atheism. His fame, which had now spread far and wide, obliged him sometimes to interrupt his philosophical reveries. Learned men visited him from all quarters. While the prince of Condé commanded the French army in Utrecht, he intreated Spinoza to visit him; and though he was absent when the philosopher arrived, he immediately returned and spent a considerable time with him in conversation. The elector Palatine offered to make Spinoza professor of philosophy at Heidelberg; but this offer he thought it expedient to decline. He died of consumption at the Hague on the 21st February 1677, at the age of forty-five. His life was a perpetual contradiction to his opinions. He was temperate, liberal, and remarkably disinterested; he was sociable, affable, and friendly. His conversation was agreeable and instructive, and never deviated from the strictest propriety.

Soon after his death appeared a thick volume entitled "*B. d. S. Opera Posthuma*." [Amstelodami] 1677, 4to. A collective edition of his works has been published in the course of the present century: "*Benedicti de Spinoza Opera quae supersunt omnia. Iterum edenda curavit, praefationes, vitam auctoris, nec non notitias quae ad historiam*

Spinoza.

Spiral
||
Spoils.Spolank
||
Sporades,

scriptorum pertinent, addidit Henr. Eberh. Gottlob Paulus, Ph. ac Th. D. hujus Prof. Ord. Jenensis." Jenae, 1802-3, 2 tom. 8vo. Spinoza has generally been considered as the author of a tract entitled "Lucii Antistii Constantis de Jure Ecclesiasticorum liber singularis." Alethopoli, 1666, 8vo. It has also been ascribed to Meyer, his friend and physician; but Leibnitz believed the author to have been Van den Hoof, who wrote "L'Intérêt de la Hollande," and various other works.¹

SPIRAL, in *Geometry*, a curved line of the circular kind, which in its progress recedes from its centre.

SPIRE, or **SPEYER**, a city of Bavaria, in the province of the Rhine, the capital of a canton of the same name. It contains no less than fifteen Catholic and two Lutheran churches, though not more than 740 houses with 3900 inhabitants, having greatly declined from its former extent and celebrity. Here the reformers of Germany, in 1529, entered a protest against the proceedings of the Diet, and thus obtained the name of Protestants. Lat. 49. 18. 51. Long. 8. 31. 13. E. The bishopric, which was very rich, was secularized in 1795, when the French seized the country, and occupied it till the general peace in 1814.

SPIRE, in *Architecture*, was used by the ancients for the base of a column, and sometimes for the astragal or tore; but among the moderns it denotes a steeple that continually diminishes as it ascends, whether conically or pyramidally.

SPIRIT, in *Metaphysics*, an incorporeal being or intelligence; in which sense God is said to be a spirit, as are angels and the human soul.

SPIRIT, in *Chemistry* and *Pharmacy*, a name applied to every volatile liquid which is not insipid like phlegm or water; and hence the distinction into acid, alkaline, and vinous spirits.

SPLICING, in the sea-language, is the untwisting the ends of two cables or ropes, and working the several strands into one another by a fidd, so that they become as strong as if they were but one rope.

SPLUGEN, a village of Switzerland, remarkable from its position as the highest inhabited part of the most ancient road across the Alps, leading into the Austrian part of Italy from the countries through which the river Rhine passes. It is in the canton of the Grisons, and in the bailiwick of Schams. It contains a good hotel, which is also the post-house, where relays of horses are always to be procured. It is 5928 feet above the level of the sea, and is surrounded with mountains of which the summits are perpetually covered with snow. The descent from this spot, on both sides, excites the admiration of all travellers. To the south the road has been formed by the Austrian government. It is carried in traverses along the front of the rocky precipices, is of great breadth, with a very gradual descent; and in several parts there are long galleries, covered with bomb-proof arches, to prevent the road from being choaked by avalanches, or by the enormous masses of rocks that sometimes are liable to fall from the lofty summits. The road that descends on the northern side has been formed by the canton of the Grisons, and is tolerably good, but is not equal to the Austrian portion. The descent to Andeer is made with neither risk nor difficulty, and at that village, where here is a good hotel and post-house, the most picturesque scenery commences. This road leads to Tussis, through what from antiquity has received the name of the *Via mala*. It follows the course of the Rhine, sometimes far above it, sometimes close to its gulf, and frequently passing over it by strongly built bridges. It has two arched passages, cut with vast labour out of the solid rock. Splugen is sixteen miles from Chiavenna, in the Austrian territory; and twenty from Tussis, in the canton of the Grisons.

SPOILS, whatever is taken from the enemy in time of war.

Among the ancient Greeks, the spoils were divided among the whole army, only the general's share was the largest; but among the Romans, the spoils belonged to the republic.

SPOLANK, a village on the south coast of Java, near to which are hot mineral springs, which raise Fahrenheit's thermometer to 122°. It is 104 miles south from Samarang.

SPOLETO, one of the delegations into which the dominions of the church in Italy are divided. It extends over 1401 square miles, contains six cities, fourteen towns, and 204 villages, with 102,053 inhabitants. The capital is the city of the same name, at the foot of a hill, and on a brook which flows to the Maragia. It is the seat of a bishop, and likewise of the civil tribunals. Besides a cathedral and twenty-two parish churches, it contains twenty-two monasteries, with some hermitages and establishments of brotherhoods of devotion. The streets are narrow and crooked, the houses old and many of them dilapidated; but the city contains 7000 inhabitants. A magnificent aqueduct supplies it with water. There are many interesting remains of antiquity, and among others, a triumphal arch of Hannibal, ruins of a theatre, of a temple of Concord, of Jupiter, and of Mars, and of a palace of Theodoric. Lat. 42. 44. 50. Long. 13. 1. E.

SPONDEE, in ancient poetry, a foot consisting of two long syllables, as *omnes*.

SPONGIA, **SPONGE**; a genus of animals. It is fixed, flexible, and very torpid, growing in a variety of forms, composed either of reticulated fibres, or masses of small spines interwoven together, and clothed with a living gelatinous flesh, full of small mouths or holes on its surface, by which it sucks in and throws out the water. As early as the days of Aristotle, sponges were supposed to possess animal life; the persons employed in collecting them having observed them shrink when torn from the rocks, thus exhibiting symptoms of sensation. The same opinion prevailed in the time of Pliny; but no attention was paid to this subject till Marsigli examined them, and declared them vegetables. Dr. Peysonell, in a paper which he sent to the Royal Society in the year 1752, and in a second in 1757, affirmed they were not vegetables, but the production of animals; and he has accordingly described the animals, and the process which they performed in making the sponges. Mr. Ellis, in the year 1762, was at great pains to discover these animals. For this purpose he dissected the *spongia urens*, and was surprised to find a great number of small worms of the genus of *nerëis* or sea scolopendra, which had pierced their way through the soft substance of the sponge in quest of a safe retreat. That this was really the case he was fully assured, by inspecting a number of specimens of the same kind of sponge, just fresh from the sea. He put them into a glass filled with seawater; and then, instead of seeing any of the little animals which Dr. Peysonell described, he observed the papillæ or small holes with which the papillæ are surrounded contract and dilate themselves. He examined another variety of the same species of sponge, and plainly perceived the small tubes inspire and expire the water. He therefore concluded that the sponge is an animal, and that the ends or openings of the branched tubes are the mouths by which it receives its nourishment, and discharges its excrements.

SPONSORS are those persons who, in the office of baptism, answer or are sureties for the persons baptized.

SPONTANEOUS, a term applied to such motions of the body and operations of the mind as we perform of ourselves without any constraint.

SPOONING, in the sea-language, is said of a ship which, being under sail in a storm at sea, is unable to bear it, and consequently forced to go right before the wind.

SPORADES, among ancient astronomers, a name given to such stars as were not included in any constellation.

¹ Leibnitz, *Essais de Theodicée*, p. 371.

Sporadic
||
Sprat.

SPORADIC DISEASES, among physicians, are such as seize particular persons at any time or season, and in any place; in which sense they are distinguished from epidemical and endemical diseases.

SPOTSWOOD, JOHN, archbishop of St. Andrews, was descended from the lairds of Spotswood in the county of Berwick, and was born in the year 1565, being the son of John Spotswood, minister of Calder, and one of the superintendents. He was educated in the university of Glasgow, and succeeded his father in the parsonage of Calder when but eighteen years of age. In 1601 he attended Lodowick duke of Lennox as his chaplain, in an embassy to the court of France for confirming the ancient amity between the two nations, and returned in the ambassador's retinue through England. When he entered upon the archbishopric of Glasgow, he found there was not a L.100 sterling of yearly revenue left; yet such was his care for his successors, that he greatly improved it, and much to the satisfaction of his diocese. After having filled this see eleven years, he was raised to that of St. Andrews in 1615, and thus became primate and metropolitan of all Scotland. He presided in several assemblies for bringing the Church of Scotland to some degree of uniformity with that of England. He continued in high esteem with King James VI., nor was he less valued by King Charles I., who was crowned by him in 1633, in the abbey-church of Holyroodhouse. In 1635, upon the death of the earl of Kinnoull, chancellor of Scotland, the primate was advanced to that post; but he had scarcely held it four years, when the confusions beginning in Scotland, he was obliged to retire into England; and being broken with age, grief, and sickness, died at London on the 26th of December 1639, and was interred in Westminster Abbey. The only work which he is known to have published bears the title of "*Refutatio Libelli de Regimine Ecclesiæ Scoticanæ*." Lond. 1620, 8vo. This was an answer to a tract of Calderwood, who replied in the *Vindiciæ* subjoined to his *Altare Damascenum*. A more considerable work was published several years after his death: "*The History of the Church and State of Scotland, beginning the year of our Lord 203, and continued to the end of the reign of James the VI. of ever blessed memory*." Lond. 1655, fol. An Appendix was afterwards added by Thomas Middleton.

The character of Spotswood is thus delineated by Laing: "In prosperity his behaviour was without moderation, in adversity without dignity; but the character of a leading, aspiring prelate has either been unduly extolled, or unjustly degraded. As a scholar and an historian he excelled his contemporaries; and it was his peculiar felicity, that his erudition was neither infected with the pedantry, nor confined to the polemical disputes of the age. His abilities recommended him first to preferment; but his ambitious views were chiefly promoted by the supple, insinuating habits of craft and intrigue. His revenge was formidable to the nobility and officers of state, oppressive to the clergy, and, joined with an inordinate ambition, ultimately ruinous to his own order."¹

SPRAT, THOMAS, bishop of Rochester, was born in 1636 at Tallaton in Devonshire. He received his education at Oxford, and after the Restoration entered into holy orders. He became fellow of the Royal Society, chaplain to George duke of Buckingham, and chaplain in ordinary to King Charles II. In 1667 he published the *History of the Royal Society*, and a *Life of Mr. Cowley*; who, by his last will, left to his care his printed works and MSS., which were accordingly published by him. In 1668 he was installed prebendary of Westminster; in 1680, was appointed canon of Windsor; in 1683, dean of Westminster; and in 1684, consecrated to the bishopric of Rochester. He was clerk

Spray
||
Spring.

of the closet to King James II.; in 1685, was made dean of the chapel royal; and the year following, was appointed one of the commissioners for ecclesiastical affairs. In 1692 his lordship, with several other persons, was charged with treason by two men, who drew up an association, in which they whose names were subscribed declared their resolution to restore King James; to seize the princess of Orange, dead or alive; and to be ready with 30,000 men to meet King James when he should land. To this they put the names of Sancroft, Sprat, Marlborough, Salisbury, and others. The bishop was arrested, and kept at a messenger's, under a strict guard, for eleven days. His house was searched, and his papers seized, among which nothing was found of treasonable appearance, except one memorandum, in the following words: "*Thorough-paced doctrine*." Being asked at his examination the meaning of the words, he said, that about twenty years before, curiosity had led him to hear Daniel Burgess preach; and that being struck with his account of a certain kind of doctrine, which he said "entered at one ear, and pacing through the head went out at the other," he had inserted the memorandum in his table-book, that he might not lose the substance of so strange a sermon. His innocence being proved, he was set at liberty, when he published an account of his examination and deliverance; which made such an impression upon him, that he commemorated it through life by an yearly day of thanksgiving. He lived to the seventy-seventh year of his age, and died May 20, 1713. His works, besides a few poems of little value, are, "*The History of the Royal Society*," "*The Life of Cowley*," "*An Answer to Sorbiere*," "*The History of the Rye-house Plot*," "*The Relation of his own Examination*," and a volume of "*Sermons*." Dr. Johnson says, "I have heard it observed with great justness, that every book is of a different kind, and that each has its distinct and characteristic excellence."

SPRAY, the sprinkling of the sea, which is driven from the top of a wave in stormy weather. It differs from spoon-drift, as being only blown occasionally from the broken surface of a high wave; whereas the latter continues to fly horizontally along the sea, without intermission, during the excess of a tempest or hurricane.

SPRING, in *Natural History*, a fountain or source of water rising out of the ground. Many have been the conjectures of philosophers concerning the origin of fountains, and great pains have been taken both by the members of the Royal Society and those of the Academy of Sciences at Paris, in order to ascertain the true cause. It was Aristotle's opinion, and held by most of the ancient philosophers after him, that the air contained in the caverns of the earth, being condensed by cold near its surface, was thus changed into water; and that it made its way where it could find a passage. But we have no experience of any such transmutation of air into water.

Those who imagine that fountains owe their origin to waters brought from the sea by subterraneous ducts, give a tolerable account how they lose their saltiness by percolation as they pass through the earth: but they find great difficulty in explaining by what power the water rises above the level of the sea to near the tops of mountains, where springs generally abound; it being contrary to the laws of hydrostatics, that a fluid should rise in a tube above the level of its source. They have however found two ways by which they endeavoured to extricate themselves from this difficulty. The one is that of Des Cartes, who imagines that after the water has become fresh by percolation, it is raised out of the caverns of the earth in vapour towards its surface; where meeting with rocks near the tops of mountains in the form of arches or vaults, it adheres to them, and, like water in an alembic, runs down their sides, till

¹ Laing's *History of Scotland*, vol. iii. p. 154.

Spring. it meets with proper receptacles, from which it supplies the fountains. Now this is a mere hypothesis, without foundation or probability: for, in the first place, we know of no internal heat of the earth sufficient to cause such evaporation; or if that were allowed, yet it is quite incredible that there should be any caverns so smooth and void of protuberances as to answer the ends of an alembic, in collecting and condensing the vapours together in every place where fountains arise. Varenus, and others, suppose that the water may rise through the pores of the earth, as through capillary tubes, by attraction. But here they show that they are quite unacquainted with what relates to the motion of a fluid through such tubes: for when a capillary tube opens into a cavity at its upper end, or grows larger and larger, so as to cease to be capillary at that end, the water will not ascend through that tube into the cavity, or beyond where the tube is capillary; because that part of the periphery of the cavity, which is partly above the surface of the water, and partly below it, is not of the capillary kind. Nay, if the cavity is continually supplied with water, it will be attracted into the capillary tube, and run down it as through a funnel, if the lower end is immersed in the same fluid, as in this case it is supposed to be.

It has been a generally received opinion, and much espoused by Mariotte, a diligent observer of nature, that the rise of springs is owing to the rains and melted snow. According to him, the rain-water which falls upon the hills and mountains, penetrating the surface, meets with clay or rocks contiguous to each other; along which it runs, without being able to penetrate them, till, having descended to the bottom of the mountain, or to a considerable distance from the top, it breaks out of the ground, and forms springs.

In order to examine this opinion, Mr. Perrault, De la Hire, and Sideleau, endeavoured to make an estimate of the quantity of rain and snow that falls in the space of a year, with the view of ascertaining whether it would be sufficient to afford a quantity of water equal to that which is annually discharged into the sea by the rivers. The result of their inquiries was, that the quantity of rain and snow which fell in a year into a cylindrical vessel would, if secured from evaporating, fill it to the height of about nineteen inches. This quantity, Sideleau shewed, was not sufficient to supply the rivers; for those of England, Ireland, and Spain, discharge a greater quantity of water annually, than the rain, according to that experiment, is able to supply. Another observation was made by them at the same time, viz., that the quantity of water raised in vapour, one year with another, amounted to about thirty-two inches, which is thirteen more than falls in rain; a plain indication that the water of fountains is not supplied by rain and melted snow.

Thus the true cause of the origin of fountains remained undiscovered, till Dr. Halley, in making his celestial observations upon the tops of the mountains at St. Helena, about eight hundred yards above the level of the sea, found, that the quantity of vapour which fell there, even when the sky was clear, was so great, that it very much impeded his observations, by covering his glasses with water every half-quarter of an hour; and he attempted to determine by experiment the quantity of vapour exhaled from the surface of the sea, as far as it rises from heat, in order to try whether that might be a sufficient supply for the water continually discharged by fountains. The process of his experiment was as follows. He took a vessel of water salted to the same degree with that of sea water, in which he placed a thermometer; and by means of a pan of coals brought the water to the same degree of heat which is observed to be that of the air in our hottest summer; he then fixed the vessel of water with the thermometer in it to one end of a pair of scales, and exactly counterpoised it with weights on the other. At the end of two hours, he found, by the alteration made in the weight of the vessel, that about a

sixtieth part of an inch of the depth of the water was gone off in vapour; and therefore, in twelve hours, one tenth of an inch would have gone off. Now, this accurate observer allows the Mediterranean sea to be forty degrees long, and four broad, the broader parts compensating for the narrower, so that its whole surface is one hundred and sixty square degrees; which, according to the experiment, must yield at least 5,280,000,000 tons of water. In this account no regard is had to the wind and the agitation of the surface of the sea, both which undoubtedly promote the evaporation. It now remained to compare this quantity of water with that which is daily conveyed into the same sea by the rivers. The only mode of proceeding was to compare them with some known river, and accordingly he takes his computation from the river Thames; and, to avoid all objections, makes allowances, probably greater than what were absolutely necessary.

The Mediterranean receives the following considerable rivers, viz., the Ebro, the Rhone, the Tiber, the Po, the Danube, the Niester, the Borysthenes, the Tanais, and the Nile. Each of these he supposes to bring down ten times as much water as the Thames, and he thus makes an allowance for smaller rivers which fall into the same sea. The Thames, then, he finds by measurement, to discharge about 20,300,000 tons of water a-day. If, therefore, the above nine rivers yield ten times as much water as the Thames, it will follow, that all of them together yield but 1827 millions of tons in a day, which is little more than one-third of what is proved to be raised in vapour out of the Mediterranean in the same time. Here, therefore, we have a source abundantly sufficient for the supply of fountains.

Now, having found that the vapour exhaled from the sea is a sufficient supply for the fountains, he proceeds, in the next place, to consider the manner in which they are raised, and how they are condensed into water again, and conveyed to the source of springs. He considers, that if an atom of water expanded into a shell or bubble, so as to be ten times as large in diameter, as when it was water, that atom would become specifically lighter than air; and therefore would rise so long as the warmth which first separated it from the surface of the water should continue to distend it to the same degree; and consequently, that vapours may be raised from the surface of the sea in that manner, till they arrive at a certain height in the atmosphere, at which they find air of equal specific gravity with themselves. Here they will float, till, being condensed by cold, they become specifically heavier than the air, and fall down in dew; or, being driven by the winds against the sides of mountains (many of which far surpass the usual height to which the vapours would of themselves ascend,) are compelled by the stream of the air to mount up with it to the tops of them; where, being condensed into water, they presently precipitate, and gleeing down by the crannies of the stones, part of them enters into the caverns of the hills; which being once filled, all the overplus of water that comes thither, runs over by the lowest place, and breaking out by the sides of the hills, forms single springs. Many of these running down by the valleys between the ridges of the hills, and coming to unite, form little rivulets or brooks; many of these again meeting in one common valley, and gaining the plain ground, being grown less rapid, become a river; and many of these being united in one common channel, make such streams as the Rhine and the Danube; which latter, he observes, one would hardly think to be a collection of water condensed out of vapour, unless we consider how vast a tract of ground that river drains, and that it is the sum of all those springs which break out on the south side of the Carpathian mountains, and on the north side of the immense ridge of the Alps, which is one continued chain of mountains from Switzerland to the Black Sea.

Thus one part of the vapours which are blown on the

Spring.

Spring.

land is returned by the rivers into the sea from whence it came. Another part falls into the sea before it reaches the land; and this is the reason why the rivers do not return so much water into the Mediterranean as is raised in vapour. A third part falls on the low lands, where it affords nourishment to plants; yet it does not rest there, but is again exhaled in vapour by the action of the sun, and is either carried by the winds to the sea to fall in rain or dew there, or else to the mountains to become the sources of springs.

It is not however to be supposed that all fountains can be referred to one and the same cause. Some proceed from rain and melted snow, which, subsiding through the surface of the earth, makes its way into certain cavities, and thence issues out in the form of springs; because the waters of several are found to increase and diminish in proportion to the rain which falls. Others, again, especially such as are salt, and spring near the sea-shore, owe their origin to sea-water percolated through the earth; and some to both these causes; though without doubt most of them, and especially such as spring near the tops of high mountains, receive their waters from vapours, as before explained.

This reasoning of Dr. Halley's is confirmed by more recent observations and discoveries. It is now found, that though water is a tolerable conductor of the electric fluid, dry earth is an electric *per se*, consequently the dry land must always be in an electrified state, compared with the ocean. It is also well known, that such bodies as are in an electrified state, whether *plus* or *minus*, will attract vapour, or other light substances that come near them. Hence the vapours that are raised from the ocean must necessarily have a tendency to approach the land in great quantity, even without the assistance of the wind, though this last must undoubtedly contribute greatly towards the same purpose, as Dr. Halley justly observes. In like manner, the higher grounds are always in a more electrified state than the lower ones; and hence the vapours having once left the ocean and approached the shore, are attracted by the high mountains; of which Mr. Pennant gives an instance in Snowdon. Hence we may see the reason why springs are so common in the neighbourhood of mountains, they being so advantageously formed in every respect for collecting and condensing the vapours into water.

The heat of springs is generally the same with the mean temperature of the atmosphere. The mean temperature of the south of England is 48° ; in Scotland, near Edinburgh, it is 45° ; in the north of Ireland it is 48° , and on the south coast about 51° . At Upsala, in Sweden, it is 43° , and in Paris 53° . According to accurate experiments made by eminent philosophers, the heat of the springs in these different countries corresponds with the medium temperature. We have not heard that similar experiments have been made in other countries, or we should have been careful to collect them. We do not however doubt but they have been made in most countries of Europe; yet we suspect little attention has been paid to this subject within the tropical regions.

Though this coincidence of the heat of springs with the mean temperature of the climate where they flow, seems to be a general fact, yet it admits of many exceptions. In various parts of the world there are springs which not only exceed the mean temperature, but even the strongest meridian heat ever known in the torrid regions. The following table will give a distinct notion of the degrees of heat which different springs have been found to possess, according to the experiments of philosophers. It is necessary to remark that experiments made upon the same springs, by different persons, vary a little from one another, which may be owing to many accidents easily accounted for. Where this is the case, we shall mention both the lowest and highest degree of heat which has been ascribed to the same spring, according to Fahrenheit's thermometer.

Spring.

Places.	Springs.	Highest degree of heat.	Lowest degree of heat.
Bristol,.....	{ St. Vincent's or { the hot well, }	84	76
Buxton,.....	Gentleman's bath,....	82	...
Matlock,.....	...	69	...
Bath,.....	King's bath,.....	119	113
Aix-la-Chapelle,....	...	146	136
Barege,.....	...	122	...
Pisa,.....	...	104	...
Caroline baths in { Bohemia,..... }	Prudel or furious,....	165	...
Iceland,.....	Geyser,.....	212	...

In cold countries where congelation takes place, the heat of the earth is considerably above the freezing point, and continues so through the whole year. From experiments that have been made in mines and deep pits, it appears that this heat is uniform and stationary at a certain depth. But as the heat of these springs far exceeds the common heat of the internal parts of the earth, it must be occasioned by causes peculiar to certain places; but what these causes are, it is no easy matter to determine. We are indeed certain that hot springs receive their heat from some subterranean cause; but it is a matter of difficulty to investigate how this heat is produced and preserved. Theories have however been formed on this subject. The subterranean heat has been ascribed to the electrical fluid, and to a great body of fire in the centre of the earth; but we suspect that the nature of the electrical fluid and its effects are not sufficiently understood. As to the supposition that the heat of springs is owing to a central fire, it is too hypothetical to require any refutation. From what then does this heat originate, and whence is the fuel which has produced it for so many ages? To enable us to answer these questions with precision, more information is necessary than we have hitherto obtained respecting the structure of the internal parts of the earth. It is peculiarly requisite that we should be made acquainted with the fossils which are most common in those places where hot springs abound. We should then perhaps discover that hot springs always pass through bodies of a combustible nature. It is well known to chemists, that when water is mixed with vitriolic acid, a degree of heat is produced superior to that of boiling water. It is also an established fact, that when water meets with pyrites, that is, a mixture of sulphur and iron, a violent inflammation takes place. If therefore we could prove that these materials exist in the strata from which hot springs are derived, we should be enabled to give a satisfactory account of this curious phenomenon. As some apology for this supposition, we may add, that most of the hot springs mentioned above, have been found by analysis to be impregnated with sulphur, and some of them with iron. It must however be acknowledged, that the hot springs of Iceland, which are 212° , the heat of boiling water, according to an accurate analysis of their contents by the ingenious Dr. Black, were neither found to contain iron nor sulphur. It will be necessary that we should wait with patience, and continue to collect facts, till the sciences of chemistry and mineralogy shall be so far advanced as to enable us to form a permanent theory on this subject.

Springs are of different kinds. Some are perennial, or continue to flow during the whole year; others flow only during the rainy season; some ebb and flow. At Torbay there is one of this kind, which ebbs and flows five or six inches every hour. There is another near Coriso in Italy, which ebbed and flowed three times a-day in the time of Pliny, and continues to do so still. A spring near Henley

Spring sometimes flows for two years together, and then dries up for an equal period.

Spurzheim. SPRING, in *Mechanics*, denotes a thin piece of tempered steel, or other elastic substance, which, being wound up, serves to put machines in motion by its elasticity, or endeavours to unbend itself. Such is the spring of a watch, clock, or the like.

SPRING, *Ver*, in cosmography, denotes one of the seasons of the year; commencing, in the northern parts of the world, on the day when the sun enters the first degree of Aries, which is about the 10th day of March, and ending when the sun leaves Gemini; or, more strictly and generally, the spring begins on the day when the distance of the sun's meridian altitude from the zenith, being on the increase, is at a medium between the greatest and least. The end of the spring coincides with the beginning of summer.

SPRIT, a small boom or pote which crosses the sail of a boat diagonally, from the mast to the upper hindmost corner of the sail, which it is used to extend and elevate; the lower end of the sprit rests in a sort of wreath or collar, called the *smotter*, which encircles the mast in that place.

SPURZHEIM, JOHN GASPAR, the pupil and colleague of Dr. Gall in the elucidation of the structure and functions of the brain, was born near Treves, on the 31st of December 1776. His father, who cultivated a farm in that district, at first intended him for the church; but, after prosecuting his studies with this view, a change of purpose took place, and young Spurzheim went in 1799 to acquire a medical education at Vienna, where he soon became acquainted with Dr. Gall. The views of that physician concerning the brain proved so interesting to him, that, after bestowing attention upon them for several years, he at length, in 1804, became the associate of his master. In the following year, when Gall was forced by the Austrian government to leave Vienna (See GALL, F. J.), Spurzheim accompanied him in his travels through Germany, France, and Denmark. In 1807 they settled in Paris, and next year presented to the Institute a memoir of their anatomical discoveries. A committee, of which Cuvier was the leading member, was appointed to give an opinion of it: a translation of their unfavourable, and, as the phrenologists say, uncandid report, will be found in the *Edinburgh Medical and Surgical Journal* for January 1809. This report being unsatisfactory to Gall and Spurzheim, they published their memoir, and a defence of it, under the title of "*Recherches sur le Système Nerveux en général, et sur celui du Cerveau en particulier*," 4to, 1809. In 1810 was commenced the publication of the "*Anatomie et Physiologie du Système Nerveux en général, et du Cerveau en particulier*;" par F. J. Gall et G. Spurzheim," 4to; a work which was not completed till 1819. The third and fourth volumes were published after Spurzheim's separation from Gall in 1813, and bear the name of the latter alone. It is illustrated by a magnificent folio atlas, containing 100 plates. The physiological portion of this work was afterwards reprinted in 6 vols. 8vo, by Dr. Gall, with his own name only, under the title "*Sur les Fonctions du Cerveau*."

Having left Dr. Gall, Spurzheim, after taking his degree of doctor of physic at Vienna, came over to Britain in 1814, for the purpose of diffusing the new doctrines about the brain. His first step was the publication of "*The Physiognomical System of Drs. Gall and Spurzheim*," 8vo, London, 1815; followed by "*Outlines of the Physiognomical System*," 12mo, 1815, and "*Observations on the Deranged Manifestations of Mind, or Insanity*," 8vo, 1817. The anatomical and physiological views expounded in the first of these works, having been violently assailed by the late Dr. John Gordon in the 25th volume of the *Edinburgh Review*, Spurzheim suddenly made his appearance in the northern metropolis, and in the lecture-room of his opponent

demonstrated by dissection the accuracy of his anatomical assertions. To the hostile article referred to, he also replied at considerable length in his "*Examination of the Objections made in Britain against the Doctrines of Gall and Spurzheim*," 8vo, Edinb. 1817. After lecturing in London, Dublin, Edinburgh, and other towns in the United Kingdom, he returned in 1817 to Paris, where he continued to lecture and publish till 1825. The works which he produced during this period are, "*Observations sur la Folie, ou sur les Dérangemens des Fonctions Morales et Intellectuelles de l'Homme*," 8vo, 1818; "*Observations sur la Phrénologie, ou la Connaissance de l'Homme Morale et Intellectuel, fondée sur les Fonctions du Système Nerveux*," 8vo, 1818; and "*Essai Philosophique sur la Nature Morale et Intellectuelle de l'Homme*," 8vo, 1820. His English work, entitled, "*View of the Elementary Principles of Education, founded on the Study of the Nature of Man*," 12mo, appeared at Edinburgh in 1821, and was reprinted, with considerable additions, in 8vo, at London, in 1828. A French edition was published at Paris in 1822. A prohibition in 1824, by the French government, of the delivery of lectures without its special permission, obliged Spurzheim to confine himself to private conversations in his own house, and induced him in the following year to revisit Britain. While residing in London, where he gave several courses of lectures and dissections of the brain, he produced his "*Phrenology, or the Doctrine of the Mind and of the Relations between its Manifestations and the Body*," and "*A View of the Philosophical Principles of Phrenology*," both 8vo, 1825: these are extended editions of some of the chapters of the *Physiognomical System*. He returned to Paris, but again visiting England in 1826, lectured to overflowing audiences in the London Institution, and in the same year published "*Phrenology in Connexion with the Study of Physiognomy*," 8vo, with 34 plates; also "*The Anatomy of the Brain, with a General View of the Nervous System*," 8vo, with 11 plates. Towards the end of this year, he lectured at Cambridge; and after expounding his views in Bath and Bristol, delivered, in April 1827, a course of lectures to seven hundred auditors, in the London Institution. His "*Outlines of Phrenology*" were published in the same year, at the close of which he visited Hull, whence he once more proceeded to Edinburgh, delivering in that city two courses of popular lectures, besides a professional course on the anatomy, physiology, and pathology of the brain. From Edinburgh he proceeded to Glasgow, and afterwards to London, where he had now fixed his residence. In 1828 appeared his "*Sketch of the Natural Laws of Man*," 12mo; and on 14th May 1829, a paper of his on the brain was read before the Royal Society, into whose Transactions, however, it was refused admittance. It was published by Dr. Spurzheim as an appendix to his "*Anatomy of the Brain*," along with some pretty free "*Remarks on Mr. Charles Bell's Animadversions on Phrenology*." He this year lectured in many English towns, and in the following spring accepted of an invitation to Dublin, where he was created an honorary member of the Royal Irish Academy. After again lecturing there in 1831, he fixed his residence in Paris, and published in 1832 a small "*Manuel de Phrénologie*," which is the last of his works. For the twofold purpose of diffusing phrenology and studying the American character and institutions, he sailed for the United States on 20th June 1832. Unfortunately the climate proved detrimental to his constitution, which was injured still more by over-exertion, and incautious exposure while lecturing at Boston; the consequence was a fever, which terminated in his death on the 10th of November 1832. His remains were honoured at Boston with a public funeral, at which an oration was delivered by Dr. Follen, professor of German in Harvard University.

As a phrenologist, Dr. Spurzheim is generally regarded by his British disciples as having improved the philosophi-

Spy
||
Squaring.

cal aspect of phrenology, by classifying the facts better than Dr. Gall, and also by pursuing them farther into their philosophical, moral, and practical results. At the same time, it appears to be the opinion of many, that he sometimes proceeded to systematize prematurely, and that in his latter years he occasionally modified his views rather through caprice than from reason, or from the accumulation of new observations. It is justly objected to his writings, in comparison with those of Gall, that in announcing his discoveries, he details neither the circumstances in which they were made, nor the cases by which they are supported. There has been much controversy on the relative merits of these two physicians, in extending the boundaries of phrenology, and elucidating the anatomy of the brain. On this subject, the curious reader may consult the *Phrenological Journal*, ii. 185, vi. 307, and xi. 225; also the preface to Spurzheim's *Anatomy of the Brain*.¹

(C. F.)

SPY, a person hired to watch the actions, motions, &c. of another; particularly what passes in a camp. When a spy is discovered, he is generally treated without mercy.

SQUADRON, in military affairs, denotes a body of horse whose number of men is not fixed, but is usually from one hundred to two hundred.

SQUADRON of Ships, either implies a detachment of ships employed on any particular expedition, or the third part of a naval armament.

SQUADS, in a military sense, are certain divisions of a company into so many squads, generally into three or four. The use of forming companies into as many squads of inspection as it has serjeants and corporals, is proved by those regiments who have practised that method; as by it the irregularity of the soldiers is considerably restrained, their dress improved, and the discipline of the regiment in general most remarkably forwarded. Every officer should have a roll of his company by squads.

SQUALL, a sudden and violent blast of wind, usually occasioned by the interruption and reverberation of the wind from high mountains. These are very frequent in the Mediterranean, particularly that part of it which is known by the name of the Levant, as produced by the repulsion and new direction which the wind meets with in its passage between the various islands of the Archipelago.

SQUARE, among *Mechanics*, an instrument consisting of two rules or branches, fastened perpendicularly at one end of their extremities, so as to form a right angle. It is of great use in the description and mensuration of right angles, and laying down perpendiculars.

SQUARE-Rigged, an epithet applied to a ship whose yards are very long. It is also used in contradistinction to all vessels whose sails are extended by stays or lateen-yards, or by booms and gaffs, the usual situation of which is nearly in the plain of the keel; and hence,

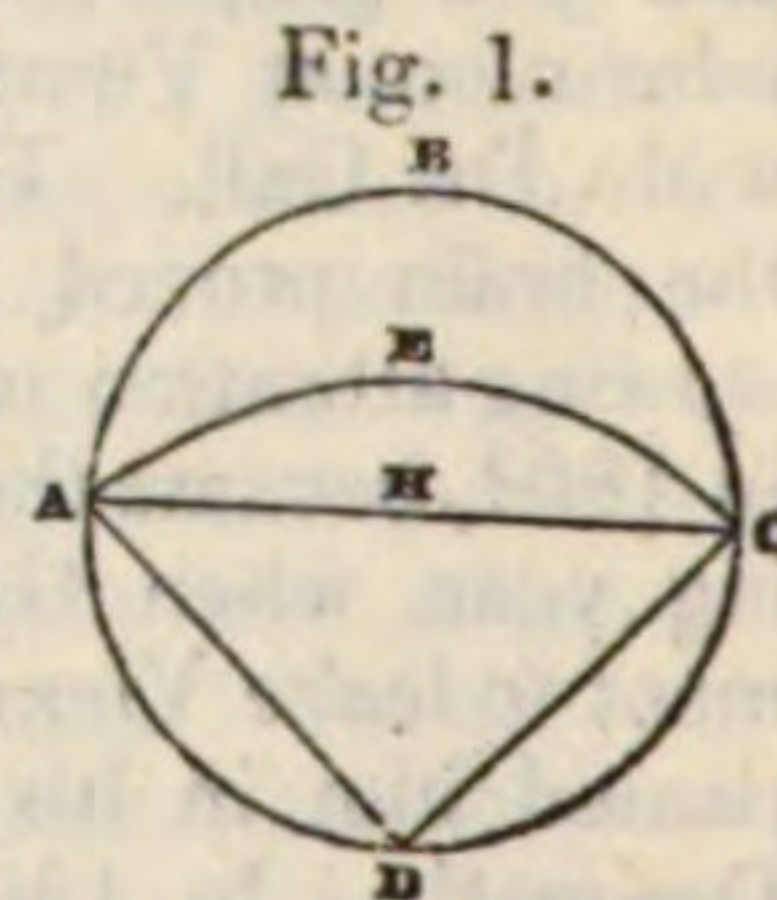
SQUARE-Sail, is a sail extended to a yard which hangs parallel to the horizon, as distinguished from the other sails which are extended by booms and stays placed obliquely. This sail is only used in fair winds, or to scud under in a tempest. In the former case, it is furnished with a large additional part, called the *bonnet*, which is then attached to its bottom, and removed when it is necessary to scud.

SQUARING, or *QUADRATURE of the Circle*, signifies the finding a square exactly equal to the area of a given circle. This problem, however, has not been, and probably cannot be, strictly resolved by the commonly admitted principles of geometry; mathematicians having hitherto been unable to do more than to find a square that shall differ from the area of any proposed circle by as small a quantity as they please. The problem is of the same degree of difficulty, and indeed may be regarded as identical with another geo-

metrical problem, namely, the *rectification of the circle*, or the finding a straight line equal to its circumference; for the area of a circle is equal to that of a rectangle contained by the radius and a straight line equal to half the circumference; therefore, if a straight line exactly equal to the circumference could be found, a rectilinear space precisely equal to the area might also be found, and the contrary. But although no perfectly accurate resolution of the problem has been obtained under either form, we can always find approximate values of the area and circumference; and it is now customary to apply the terms *quadrature* and *rectification* of the circle also to these.

The problem of the quadrature of the circle appears to have engaged the attention of geometers at a very early period; for we are told that Anaxagoras, who lived about five hundred years before Christ, attempted its solution while confined in prison on account of his philosophical opinions. We are ignorant of the result of his researches; but although we cannot suppose they were attended with any success, we may reasonably conclude that we are indebted to them for the discovery of some of the properties of the figure, which are now known as elementary propositions in geometry.

Hippocrates of Chios was likewise engaged in trying to resolve the same problem, and it was no doubt in the course of his inquiries into this subject, that he discovered the quadrature of the curvilinear space, which is now known by the name of the *Lune of Hippocrates*. The nature of this discovery may be briefly explained as follows. Let ABCD be a circle, H its centre, AC its diameter, ADC a triangle inscribed in the semicircle, having its sides, AD, DC equal to one another. On D as a centre, with DA or DC as a radius, let the quadrantal arch AEC be described, then shall the curvilinear space bounded by the semicircle ABC and the quadrantal arch AEC (which is the *Lune of Hippocrates*), be equal to the rectilinear triangle ADC.



Although Hippocrates's discovery has led to no important conclusion either relating to the quadrature of the circle or that of any other curve, yet at the time it was made, it might be regarded as of some consequence, chiefly because it shewed the possibility of exhibiting a rectilinear figure equal to a space bounded by curve lines, a thing which we have reason to suppose was then done for the first time, and might have been fairly doubted, considering the insuperable difficulty that was found to attend the quadrature of the circle or its rectification.

Aristotle speaks of two persons, namely, Bryson and Antiphon, who, about his time, or a little earlier, were occupied with the quadrature of the circle. The former appears, according to the testimony of Alexander Aphrodisæus, to have erred most egregiously; he having concluded that the circumference was exactly $3\frac{1}{2}$ times the diameter. And the latter seems to have proceeded in the same manner as Archimedes afterwards did in squaring the parabola, that is, by first inscribing a square in the circle, then an isocles triangle in each of the segments of the curve, having for its base a side of the square; and next again a series of triangles in the segments, having for their bases the sides of the former series, and so on. This mode of procedure, however, was not attended with success, as these spaces do not, as in the case of the parabola, admit of being absolutely summed.

It may be supposed that Archimedes exerted his utmost efforts to resolve this problem; and probably it was only

¹ *Phrenological Journal*, vol. viii; *Memoir by Carmichael*. *Foreign Quarterly Review*, vol. ii.

Squaring. after long meditation on the subject that he lost all hopes of success, and contented himself with that approximation to the ratio of the diameter to the circumference which is contained in his treatise *De Circuli Dimensione*. He found his approximation to the ratio, by supposing a regular polygon of ninety-six sides, to be described about the circle, and another of the same number, to be inscribed in it, and by shewing that the perimeter of the circumscribing polygon was less than $3\frac{1}{7}$, or $3\frac{1}{2}$ times the diameter, but that the perimeter of the inscribed figure was greater than $3\frac{1}{2}$ times the diameter; now, the circumference of the circle being less than the perimeter of the one polygon, but greater than that of the other; it follows that the circumference must be less than $3\frac{1}{2}$ times the diameter, but greater than $3\frac{1}{7}$ times; so that, taking the first of these limits, as being expressed by the smallest numbers, the circumference will be to the diameter as $3\frac{1}{2}$ to 1, or as 22 to 7 nearly.

Although the ratio found by Archimedes be the oldest known in the western world, yet one more accurate was known at a much earlier period in India. This we learn from the Institutes of Akbar (*Ayeen Akberry*), where it is said that the Hindoos suppose the diameter of a circle to be to its circumference as 1250 to 3927. Now, this ratio must have required the inscription of a polygon of 768 sides in the circle, and must have been attended with nine extractions of the square root, each carried as far as ten places of figures.

We learn from Simplicius that Nicomedes and Apollonius both attempted to square the circle, the former by means of a curve, which he called the *quadratrix*; the invention of which, however, is ascribed to Dinostratus, and the latter, by the help of a curve, denominated the sister to the tortuous line, or *spiral*, and which was probably the *quadratrix* of Dinostratus; the nature of which, and the manner of its application to the subject in question, we shall briefly explain.

Let AFB be a quadrant of a circle, (fig. 2), and C its centre; and conceive the radius CF to revolve uniformly about C, from the position CA, until at last it coincide with CB; while at the same time a line DG is carried with an uniform motion from A towards CB; the former line continuing always parallel to the latter, until at last they coincide; both motions being supposed to begin and end at the same instant; the point E, in which the revolving radius CF, and the moveable line DG intersect one another, will generate a certain curve line AEH, which is the *quadratrix* of Dinostratus.

Draw EK, FL both perpendicular to CB; then because the radius AC and the quadrantal arch AFB, are uniformly generated in the same time by the points D and F, the contemporaneous spaces described will have to one another the same ratio as the whole spaces; that is, AD : AF :: AC : AB; hence we have AC : AB :: DC, or EK : FB. Now, as the moveable point F approaches to B, the ratio of the straight line EK to the arch FB will approach to, and will manifestly be ultimately the same as the ratio of the straight line EK to the straight line FL, which again is equal to the ratio of CE to CF; therefore the ratio of the radius AC to the quadrantal arch AFB is the limit of the ratio of CE to CF, and consequently equal to the ratio of CH to CB, H being the point in which the *quadratrix* meets CB. Since therefore CH : CB :: CA, or CB : quad. arch AFB, if by any means we could determine the point H, we might then find a straight line equal to the quadrantal arch, (by finding a third proportional to CH and CB), and consequently a straight line equal to the circumference. The point H, however, cannot be determined by a geometrical construction, and there-

VOL. XX.

fore all the ingenuity evinced by the person who first Squaring. thought of this method of rectifying the circle, (which certainly is considerable), has been unavailing.

The Arabs, who succeeded the Greeks in the cultivation of the sciences, would no doubt have their pretended squavers of the circle. We however know nothing more than that one of them believed he had discovered that the diameter being unity, the circumference was the square root of 10; a very gross mistake; for the square root of 10 exceeds 3.162; but Archimedes had demonstrated that the circumference was less than 3.143.

It appears that, during the dark ages, some attempts were made at the resolution of this famous problem, which, however, have always remained in manuscripts, buried in the dust of old libraries. But upon the revival of learning, the problem was again agitated by different writers, and particularly by the celebrated Cardinal De Cusa, who distinguished himself by his unfortunate attempt to resolve it. His mode of investigation, which had no solid foundation in geometry, led him to conclude, that if a line equal to the sum of the radius of a circle, and the side of its inscribed square were made the diameter of another circle, and an equilateral triangle were inscribed in this last, the perimeter of this triangle would be equal to the circumference of the other circle. This pretended quadrature was refuted by Regiomontanus.

It would be trespassing too much upon the patience of our readers, were we to mention all the absurd and erroneous attempts which have been made during the last three centuries to square the circle. In a supplement to Montucla's *Histoire des Mathematiques*, we find upwards of forty pretenders to the honour of this discovery enumerated. They were almost all very ignorant of geometry; and many of them were wild visionaries, pretending to discover inexplicable relations between the plain truths of mathematics and the most mysterious doctrines of religion. From such persons as have generally pursued this inquiry, no improvement whatever of the science was to be expected; although, in some instances, it has derived advantage from the labours of such as have undertaken to expose the absurdity of their conclusions; as in the case of Metius, who in refuting the quadrature of one Simon à Quercu, found a much nearer approximation to the ratio of the diameter to the circumference than had been previously known in Europe, namely, that of 113 to 355.

Among the most remarkable of those who have undertaken to resolve this problem, we cannot fail to enumerate Joseph Scaliger, a man of stupendous erudition. Full of confidence in his own powers, he believed that, entering upon the study of geometry, he could not fail to surmount by the force of his genius, those obstacles which had completely stopped the progress of all preceding inquirers. He gave the result of his meditations to the world in 1592, under the title *Nova Cyclometria*; but he was refuted by Clavius, by Vieta, and others, who shewed that the magnitude which he had assigned to the circumference was a little less than the perimeter of the inscribed polygon of 192 sides, which proved beyond a doubt that he was wrong. Scaliger, however, was not to be convinced of the absurdity of his conclusion; and indeed, in almost every instance, pretenders to this discovery have not been more remarkable for their egregious errors, than for their obstinacy in maintaining that they were in the right, and all who held a contrary opinion in the wrong.

The famous Hobbes came also upon the field about the year 1650, with pretensions not only to the quadrature of the circle, but also to the trisection of an angle, the rectification of the parabola, &c.; but his pretended solutions were refuted by Dr. Wallis. And this circumstance afforded him occasion to write not only against geometers, but even against the science of geometry itself.

4 A

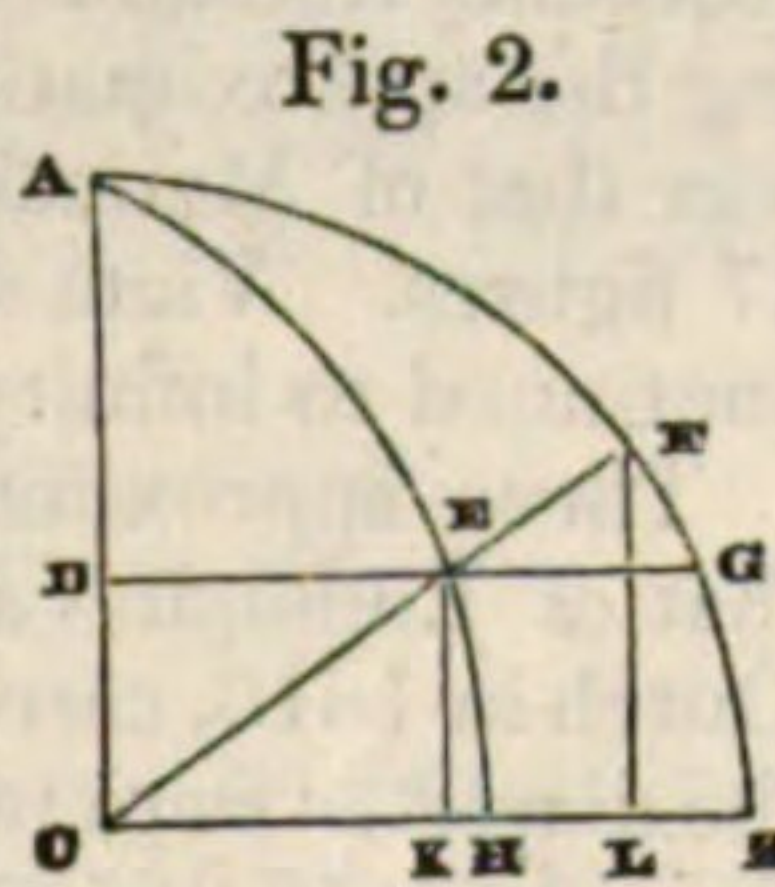


Fig. 2.

Squaring.

We find it recorded by Montucla, as a sort of phenomenon, that one Richard White, an English Jesuit, having happened upon what he conceived to be a quadrature of the circle, which he published under the title, *Chrysæspis, seu Quadratura Circuli*, suffered himself at last to be convinced by some of his friends that he was wrong. But a solution of the same problem, found out by one Mathulen of Lyon, did not end in so much advantage to its author. This man in 1728 announced to the world that he had discovered both the quadrature of the circle, and a perpetual motion; and he was so certain of the truth of these discoveries, that he he consigned 1000 *ecus* (about L.125), to be paid to any one who should demonstrate that he was deceived in either. The task was not difficult. Nicole of the Academy of Sciences demonstrated that he was wrong, and he himself allowed it; but he hesitated to pay the money, which Nicole had relinquished in favour of the Hotel Dieu of Lyon. The affair went before a court of justice, which adjudged the money to be paid, as Nicole had destined it, to the poor. At a later period, namely, in 1753, the Chevalier de Causans, a French officer, and a man who was never supposed to be a mathematician, suddenly found a quadrature of the circle in procuring a circular piece of turf to be cut; and rising from one truth to another, he explained by his quadrature the doctrine of original sin, and the Trinity. He engaged himself, by a public writing, to deposit with a notary the sum of 300,000 francs, to be wagered against such as should oppose him, and he actually lodged 10,000, which were to devolve to him who should demonstrate his error. This was easily done, as it resulted from his discovery that a circle was equal to its circumscribing square, that is, a part to the whole. Some persons came forward to answer his challenge, and in particular a young lady sued him at one of the courts of law; but the French king judged that the chevalier's fortune ought not to suffer on account of his whim; for, setting aside this piece of folly, in every other respect he was a worthy man. The procedure was therefore stopped, and the wager declared void.

We shall not enter further into the history of these vain and absurd attempts to resolve this important problem, but proceed to state what has actually been done by men of sound minds and real mathematical acquirements towards its solution. And in the first place, it may be observed that the problem admits of being proposed under two different forms; for it may be required to find either the area of the whole circle, or, which is the same thing, the length of the whole circumference; or else to find the area of any proposed sector or segment, or, which is equivalent, the length of the arch of the sector or segment. The former is termed the *definite*, and the latter the *indefinite* quadrature of the circle. The latter evidently is more general than the former, and includes it as a particular case. Now, if we could find by any means a finite algebraic equation that should express the relation between any proposed arch of a circle, and some known straight line, or lines, the magnitude of one or more of which depended on that arch, then we would have an absolute rectification of the arch, and consequently a rectification or quadrature of the whole circle. We here speak of an analytical solution; the ancients, who were almost entirely ignorant of this branch of mathematical science, must have endeavoured to treat it entirely upon geometrical principles. It is now well known, however, that all geometrical problems may be subjected to analysis; and that it is only by such a mode of proceeding they have in many cases been resolved.

With respect to the definite quadrature of the circle, no unexceptionable demonstration of its impossibility has hitherto been published. It is true, that James Gregory, in his *Vera Circuli et Hyperbolæ Quadratura*, has given what he considered as such a demonstration; but it was objected to by Huygens; one of the best geometers of his time. It

is certain that the ratio of the diameter to the circumference, also, that the ratio of the square of the diameter to the square of a straight line equal to the circumference, cannot be expressed by rational numbers, for this has been strictly demonstrated by Lambert in the Berlin Memoirs for 1761. A demonstration is also given in Legendre's *Geometrie*. As to the indefinite quadrature, if Newton's demonstration of the twenty-eighth lemma of the first book of his *Principia*, be correct, the thing ought to be absolutely impossible. For the object of that proposition is to prove, that in no oval figure whatever, that returns into itself, can the area cut off by straight lines at pleasure, be universally found by an equation of a finite dimension, and composed of a finite number of terms. If this be true, then it will be impossible to express any sector of a circle taken at pleasure in finite terms. It is however to be remarked, that the accuracy of the reasoning by which Newton has attempted to establish the truth of the general proposition, has been questioned by no less a geometer than D'Alembert; and indeed we know one oval curve, which returns into itself, and which according to Newton's proposition ought therefore not to admit of an indefinite quadrature; yet this is by no means the case, for it does really admit of such a quadrature. The curve we mean is the *lemniscata*, whose figure is nearly that of the numeral character 8. Upon the whole, then, we may infer that an unexceptionable demonstration of the impossibility of expressing either the whole circle, or any proposed sector of it, by a finite equation, is still among the *desiderata* of mathematics.

Of the different methods which have been found for approximating to the area or to the circumference, that of Archimedes is the only one found by the ancients in the western world that has descended to modern times, and it appears to have been the most accurate known, until about the year 1585, when Metius, in refuting a pretended quadrature, found the more accurate ratio of 113 to 355, as we have already noticed. About the same time Vieta and Adrianus Romanus published their ratios, the former carrying the approximation to ten decimals instead of six, (which was that of Metius's ratio), and the latter extending it to 17 figures. Vieta also gave a kind of series, which being continued to infinity, gave the value of the circle.

These approximations, however, were far exceeded by that of Ludolph Van Ceulen, who, in a work published in Dutch in 1610, carried it as far as 36 figures, showing that if the diameter were unity, the circumference would be greater than 3.14159,26535,89793,23846,26433,83279,50288, but less than the same number with the last figure increased by an unit. In finding this approximation, Van Ceulen followed the method of Archimedes, doubling continually the number of sides of the inscribed and circumscribed polygons, until at length he found two which differed only by an unit in the 36th place of decimals in the numbers expressing their perimeters. This was rather a work of patience than of genius; indeed the labour must have been prodigious. He seems to have valued highly this singular effort; for in imitation of Archimedes, whose tomb was adorned with a sphere and cylinder, he directed that the ratio he had found might be inscribed on his tomb.

Snellius abridged greatly the labour of calculation; and although he did not go beyond Van Ceulen, yet he verified his result. Des Cartes also found a geometrical construction, which being repeated continually, gave the circumference, and from which he might easily have deduced an expression in the form of a series. Gregory of St. Vincent distinguished himself also on this subject; he however committed a great error in supposing he had discovered the quadrature of both the circle and hyperbola. Gregory's mistake was the cause of a sharp controversy carried on between his disciples on the one side, and by Huygens, Mersenne, and Lestaud, on the other; and it

Squaring.

Squaring. was this that gave Huygens occasion to consider particularly the quadrature of the circle, and to investigate various new and curious theorems relating to it, which are contained in his *Theoremata de Quadratura Hyperboles, Ellipsis, et Circuli*, 1651; and in his work *De Circuli Magnitudine inventa*, 1654. In particular he showed, that if c denote the chord of an arch, and s its sine, then the arch itself will be greater than $c + \frac{1}{3}(c-s)$, but less than $c + \frac{4c+s}{2c+3s} \times \frac{1}{3}(c-s)$: he also showed that the arch is less than the sum of $\frac{2}{3}$ of its sine and $\frac{1}{3}$ of its tangent.

James Gregory, in his *Vera Circuli et Hyperbolæ Quadratura*, gave several curious theorems upon the relation of the circle to its inscribed and circumscribed polygons, and their ratios to one another; and by means of these he found with infinitely less trouble than by the ordinary methods, and even by those of Snellius, the measure of the circle as far as 20 places of figures. He gave also, after the example of Huygens, constructions for finding straight lines nearly equal to arches of a circle, and of which the degree of accuracy was greater. For example, he found that if A be put for the chord of an arch of a circle, and B for twice the chord of half the arch, and C be taken such that $A+B : B :: B : C$, then the arch itself is nearly equal to $\frac{8C+8B-A}{15}$, but a little less, the error in the case of a

complete semicircle being less than its $\frac{1}{3}\pi$ part; and when the arch does not exceed 120° , it is less than its $\frac{1}{4}\pi$ part; and finally, for a quadrant the error is not greater than its $\frac{1}{8}\pi$ part. And farther, that if D be such that $A : B ::$

B : D, then the arch is nearly equal to $\frac{12C+4B-D}{15}$, but

a little greater, the error in the semicircle being less than its $\frac{1}{1000}$ part, and in a quadrant less than its $\frac{1}{8000}$ part.

Dr. Wallis gave, in his *Arithmetica Infinitorum*, a singular expression for the ratio of the circle to the square of its diameter. He found that the former was to the latter as 1 to the product

$$\frac{3 \times 3 \times 5 \times 5 \times 7 \times 7 \times 9 \times 9 \times 11 \times 11, \&c.}{2 \times 4 \times 4 \times 6 \times 6 \times 8 \times 8 \times 10 \times 10 \times 12}$$

the fractions $\frac{5}{2}, \frac{5}{4}, \frac{5}{8}, \frac{5}{16}$, &c., being supposed infinite in number. The products being supposed continued to infinity, we have the ratio exactly; but if we stop at any finite number of terms, as must necessarily be the case in its application, the result will be alternately too great and too small, according as we take an odd or an even number of terms of the numerator and denominator.

An expression of another kind for the ratio of the circle to the square of the diameter was found by Lord Brounker. He showed that the circle being unity, the square of the diameter is expressed by the continued fraction

$$1 + \frac{1}{2 + \frac{9}{2 + \frac{25}{2 + \frac{49}{2 + \frac{81}{2 + \dots}}}}}$$

which is supposed to go on to infinity, the numerators 1, 9, 25, 49, &c., being the squares of the odd numbers 1, 3, 5, 7, &c. By taking two, three, four, &c., terms of this fraction, we shall have a series of approximate values, which are alternately greater and less than its accurate value.

Such were the chief discoveries relating to the quadrature of the circle made before the time of Newton; many others, however, were quickly added by that truly great

man, as well as by his contemporaries. In particular, James Gregory found, that t being put for the tangent, the arch is expressed by the very simple series

$$t - \frac{t^3}{3} + \frac{t^5}{5} - \frac{t^7}{7} + \frac{t^9}{9} - \&c.$$

By supposing that $t=1$, in which case the arch is one-eighth of the circumference, we have the corresponding arch expressed by the series

$$4(1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9} - \frac{1}{11} + \&c.)$$

which was also given by Leibnitz as a quadrature of the circle in the *Acta Eruditorum* in the year 1682, but was discovered by him 1673. Gregory had however found the series under its general form several years before. This series is altogether inapplicable in its present form, on account of the slowness of its convergency; for Newton has observed, that to exhibit its value exact to twenty places of figures, there would be occasion for no less than five thousand millions of its terms, to compute which would take up above a thousand years.

The slowness of the convergency has arisen from our supposing $t=1$. If we had supposed t greater than 1, then the series would not have converged at all, but on the contrary diverged. But by giving to t a value less than 1, then the rate of convergency will be increased, and that so much the more, as t is smaller.

If we suppose the arch of which t is the tangent to be 30° , then t will be $\sqrt{\frac{1}{3}} = \frac{1}{3}\sqrt{3}$, and therefore half the circumference to radius unity, or the circumference to the diameter unity, will be

$$\sqrt{12}(1 - \frac{1}{3.3} + \frac{1}{5.3^2} - \frac{1}{7.3^3} + \frac{1}{9.3^4} - \&c.).$$

Mr. Machin, enticed by the easiness of the process, was induced, about the beginning of the last century, to continue the approximation as far as 100 places of figures, thus finding the diameter to be to the circumference as 1 to 3.14159,26535,89793,23846,26433,83279,50288,41971,69399,37510,58209,74944,59230,78164,06286,20899,86280,34825,34211,70680. After him, De Lagny continued it as far as 128 figures. But he has also been outdone; for in Radcliffe's library at Oxford, there is a manuscript in which it is carried as far as 150 figures!

Although this last series, which was first proposed by Dr. Halley, gives the ratio of the diameter to the circumference with wonderful facility when compared with the operose method employed by Van Ceulen, yet others have been since found which accomplish it with still greater ease.

We have given such a method in our treatise on ALGEBRA, (see article 272.) In the same treatise, (article 273), we have given a very elementary method, which may be understood by the mere elements of geometry. For the analytical methods, see FLUXIONS. (R.)

SRAVANA BALGUTA, a village of Hindustan, in the northern province of Mysore, celebrated as the principal seat of the Jain worship, which at one time prevailed all over the south of India, but which has now greatly declined, from the influence of the Brahmins. There are two hills adjoining the town, on one of which, named Indra Betta, is situated the temple; the other is cut into a colossal statue, seventy feet in height. The village is almost wholly inhabited by Jainas. Long. 76. 43. E. Lat. 12. 45. N.

SRI MUTTRA, a considerable town of Hindustan, province of Agra. It is situated on a naked rock of red granite, of which material all the houses are constructed. The streets are very narrow, and the working of the red stone into slabs furnishes employment to the greater part of the inhabitants. Long. 77. 20. E. Lat. 26. 41. N.

Squaring
||
Sri Muttra.

Sri Perma-
tura
||
Staffa.

SRI PERMATURA, a town of the south of India, in the province of the Carnatic, celebrated as the birth-place of Rama Anuja Acharya, the great Brahmin saint and reformer, and the founder of a sect. He preached successfully against the doctrines of the Jains and the Boodhists. Long. 80. 2. E. Lat. 12. 59. N.

STABAT MATER, a musical composition upon the Latin text of a sacred cantata, beginning with these words. Pergolesi, Jomelli, and Haydn, have each set these words to music in an admirable manner.

STADE, a town of the kingdom of Hanover, in the province of Bremen, of which province it is the capital. It stands on the river Schwinge, which falls into the Elbe about one mile below the town, whence large vessels must load and discharge by the aid of river craft. Stade, which was once fortified, contains the provincial courts of law and boards of administration. It contains 5350 inhabitants, who are occupied as brewers, distillers, manufacturers of coarse woollen and hosiery, and in equipping ships for the whale fishery. Opposite the town a Hanoverian ship of war is stationed, which collects a small toll on each vessel that passes upwards to Hamburg or Altona. Lat. 53. 36. 5. Long. 9. 18. 10. E.

STADIUM, an ancient Greek measure, containing 125 geometrical paces, or 625 Roman feet, corresponding to our furlong. The Greeks usually measured distances by stadia, which they called *σταδία*. Stadium also signified the course on which their races were run.

STADTHOLDER, formerly the principal magistrate or governor of the Seven United Provinces. This office is now abolished, and that of king substituted.

STAFF, an instrument ordinarily used to rest on in walking. The staff is also frequently used as a kind of natural weapon, both of offence and defence, and for several other purposes.

STAFF, a light pole erected in different parts of a ship, for hoisting the colours.

STAFF, in *Music*, five lines, on which, with the intermediate spaces, the notes of a song or piece of music are marked.

STAFFA, one of the Hebrides or Western Islands of Scotland, remarkable for its basaltic pillars. It was visited by Sir Joseph Banks, who communicated the following account of it to Mr. Pennant: "The little island of Staffa lies on the west coast of Mull, about three leagues north-east from Iona, or Icolumbkill: its greatest length is about an English mile, and its breadth about half a one. On the east side of the island is a small bay where boats generally land, a little to the southward of which the first appearance of pillars is to be observed; they are small; and instead of being placed upright, lie down on their side, each forming a segment of a circle. From thence you pass a small cave, above which the pillars, now grown a little larger, are inclining in all directions: in one place in particular, a small mass of them very much resembles the ribs of a ship. From hence having passed the cave, which, if it is not low water, you must do in a boat, you come to the first ranges of pillars, which are still not above half as large as those a little beyond. Over against this place is a small island, called in Erse *Boo-sha-la*, separated from the main by a channel not many fathoms wide. The whole island is composed of pillars without any stratum above them; they are still small, but by much the neatest formed of any about the place.

"The first division of the island, for at high water it is divided into two, makes a kind of a cone, the pillars converging together towards the centre: on the other they are in general laid down flat: and in the front next to the main, you see how beautifully they are packed together, their ends coming out square with the bank which they form. All these have their transverse sections exact, and their surfaces

smooth, which is by no means the case with the large ones, which are cracked in all directions. I must question, however, if any part of this whole island of Boo-sha-la is two feet in diameter. Staffa.

"The main island opposite to Boo-sha-la, and farther towards the north-west, is supported by ranges of pillars pretty erect, and though not tall, (as they are not uncovered to the base), of large diameters; and at their feet is an irregular pavement, made by the upper sides of such as have been broken off, which extends as far under water as the eye can reach. Here the forms of the pillars are apparent; these are of three, four, five, six, and seven sides; but the numbers of five and six are by much the most prevalent. The largest I measured was of seven; it was four feet five inches in diameter.

"The surfaces of these large pillars, in general, are rough and uneven, full of cracks in all directions; the transverse figures in the upright ones never fail to run in their true directions. The surfaces upon which we walked were often flat, having neither concavity nor convexity; the larger number, however, was concave, though some were very evidently convex. In some places, the interstices within the perpendicular figures were filled up with a yellow spar: in one place, a vein passed in among the mass of pillars, carrying here and there small threads of spar. Though they were broken and cracked through in all directions, yet their perpendicular figures might easily be traced: from whence it is easy to infer, that whatever the accident might have been that caused the dislocation, it happened after the formation of the pillars.

"From hence proceeding along shore, you arrive at Fin-gal's Cave. Its dimensions I have given in the form of a table:

	Feet.	In.
Length of the cave from the rock without,	371	6
From the pitch of the arch,	250	0
Breadth of ditto at the mouth,	53	7
At the farther end,	20	0
Height of the arch at the mouth,	117	6
At the end,	70	0
Height of an outside pillar,	39	6
Of one at the north-west corner,	54	0
Depth of water at the mouth,	18	0
At the bottom,	9	0

"The cave runs into the rock in the direction of north-east-by-east by the compass.

"Proceeding farther to the north-west, you meet with the highest ranges of pillars, the magnificent appearance of which is past all description. Here they are bare to their very bases, and the stratum below them is also visible: in a short time it rises many feet above the water, and gives an opportunity of examining its quality. Its surface is rough, and has often large lumps of stone sticking in it as if half immersed: itself, when broken, is composed of a thousand heterogeneous parts, which together have very much the appearance of a lava; and the more so, as many of the lumps appear to be of the very same stone of which the pillars are formed. This whole stratum lies in an inclined position, dipping gradually towards the south-east. As hereabouts is the situation of the highest pillars, I shall mention my measurements of them, and the different strata in this place, premising, that the measurements were made with a line held in the hand of a person who stood at the top of the cliff, and reaching to the bottom; to the lower end of which was tied a white mark, which was observed by one who stayed below for the purpose: when this mark was set off from the water, the person below noted it down, and made signal to him above, who made then a mark in his rope: whenever this mark passed a notable place, the same signal was made, and the name of the place noted down as before: the line being all hauled up, and the distances between the marks measured and noted down, gave, when compared

Staffa. with the book kept below, the distances, as for instance in the cave:

"No. 1, in the book below, was called from the water to the foot of the first pillar in the book above; No. 1 gave 36 feet 8 inches, the highest of that ascent, which was composed of broken pillars.

"No. 1. Pillar at the west corner of Fingal's cave.

	Feet.	In.
1. From the water to the foot of the pillar,	42	10
2. Height of the pillar,	37	3
3. Stratum above the pillar,	66	9

"No. 2. Fingal's cave.

1. From the water to the foot of the pillar,	36	8
2. Height of the pillar,	39	6
3. From the top of the pillar to the top of the arch,	31	4
4. Thickness of the stratum above,	34	4
By adding together the three first measurements, we got the height of the arch from the water,	117	6

"No. 3. Corner pillar to the westward of Fingal's cave.

Stratum below the pillar of lava-like matter,	11	0
Length of pillar,	54	0
Stratum above the pillar,	61	6

"No. 5. Another part to the westward.

Stratum below the pillar,	17	1
Height of the pillar,	50	0
Stratum above,	51	1

"No. 5. Another pillar farther to the westward.

Stratum below the pillar,	19	8
Height of the pillar,	55	1
Stratum above,	54	7

"The stratum above the pillars, which is here mentioned, is uniformly the same, consisting of numberless small pillars, bending and inclining in all directions, sometimes so irregular that the stones can only be said to have an inclination to assume a columnar form; in others more regular, but never breaking into or disturbing the stratum of large pillars, whose tops everywhere keep an uniform and regular line.

"Proceeding now along the shore round the north end of the island, you arrive at *Oua na scarve*, or the Corvora's Cave. Here the stratum under the pillars is lifted up very high; the pillars above are considerably less than those at the north-west end of the island, but still very considerable. Beyond is a bay, which cuts deep into the island, rendering it in that place not more than a quarter of a mile over. On the sides of this bay, especially beyond a little valley, which almost cuts the island into two, are two stages of pillars, but small; however, having a stratum between them exactly the same as that above them, formed of innumerable little pillars, shaken out of their places, and leaning in all directions.

"Having passed this bay, the pillars totally cease; the rock is of a dark-brown stone, and no signs of regularity occur till you have passed round the south-east end of the island, (a space almost as large as that occupied by the pillars), which you meet again on the west side, beginning to form themselves irregularly, as if the stratum had an inclination to that form, and soon arrive at the bending pillars where I began.

"The stone of which the pillars are formed, is a coarse kind of basaltes, very much resembling the Giant's Causeway in Ireland, though none of them are near so neat as the specimens of the latter which I have seen at the British Museum, owing chiefly to the colour, which in ours is a dirty brown, in the Irish a fine black; indeed the whole production seems very much to resemble the Giant's Causeway."

Views of Fingal's Cave are given in plates CCCLXIV and CCCLXV, under the head MINERALOGY.

STAFFORD, the county town of Staffordshire, is 135 miles from London. It consists of two parishes, and returns two members to Parliament. It stands on the river Sow, and was once fortified. It is now well built. The principal buildings are the assize hall, the county jail, and the infirmary. It has a good free-school, several alms-houses, and on Saturday a good market, well attended. The canal encourages some trade; but the chief occupation of the inhabitants is making shoes, and some cloth is also made. The population was in 1801, 3927; in 1811, 4898; in 1821, 5775; and in 1831, 6998.

STAFFORDSHIRE, an inland English county of an oblong form. Its greatest length from north-east to south-west is about sixty, and its greatest breadth about thirty-eight, miles. It contains 1148 statute square miles, or 734,720 acres. It is bounded on the north by Cheshire, west by Shropshire, south by Worcester and Warwickshire, and east by Derbyshire. The great divisions are five hundreds; but as each of these is subdivided into the north and south portions, there are effectively ten hundreds. These contain one hundred and eighty-one parishes, twenty-three market towns, and one city. The whole of the county, with the exception of two parishes, is within the diocese of Lichfield, and comprehended within the archdeaconry of Stafford.

The population of this county at the four decennial periods of enumeration, was found to be as follow: in 1801, 239,153; in 1811, 295,153; in 1821, 341,040; and in 1831, 410,400.

In 1831, the occupiers of land employing labourers were.....	3,781
The occupiers not employing labourers.....	3,649
Labourers employed in agriculture.....	16,812
Labourers employed in manufactures.....	26,755
Labourers employed in retail trade or handicraft.....	24,766
Capitalists, bankers, &c.....	3,569
Labourers not agricultural.....	22,690
Other labourers under twenty years of age...	4,245
Males at and above twenty years.....	101,632
Male servants.....	1,959
Female servants.....	12,739

In the same year, the number of families, chiefly employed in agriculture, was found to be 18,156; of those chiefly employed in trade, manufactures, and handicraft, 43,646; and of those not comprised in either of the preceding classes, 21,789. The number of inhabited houses was 78,049, occupied by 83,593 families. The uninhabited houses were 4088, and those building 573. The annual value of the real property of the county, as assessed for the purposes of the property tax in the year 1813, was L.1,150,285.

The towns and townships within this county, and their population in 1831, were as follows, but some of them may be better described as large villages than towns.

Wolverhampton.....	48,184	Wednesbury.....	8437
Stoke-upon-Trent...	37,220	Newcastle-under-Lyne	8196
Sedgley.....	20,577	Stone.....	6918
West Bromwick.....	15,066	Stafford.....	6998
Kingswinford.....	15,156	Darlaston.....	6647
Walsall.....	15,066	Lichfield (city).....	6499
Tipton.....	14,951	Handsworth.....	4944
Burslem.....	11,250	Uttoxeter.....	4864
Wolstanton.....	10,853	Eccleshall.....	4471
Leek, the town,.....	4,374	Burton-on-Trent.....	4399
but the parish.....	10,780	Penkridge.....	2991

The middle and southern portions are generally level, but interspersed with gentle eminences. The northern division

Stafford.
Staffordshire.

Stafford-
shire.

is of an opposite character, the surface being for the most part bleak and hilly. The general elevation of this district above the southern part of the county is about two or three hundred feet; but some points rise to the height of from 1200 to 1500. Of those the most elevated are Bunster and the Weever Hills. In the valleys on the banks of the rivers are some tracks of country equal to the most beautiful parts of the island. Among these, the district betwixt Lichfield and Stone, and the picturesque banks of the Dove, especially at Ilam, are very remarkable.

The soil is various, but the strong clays are the most predominant; next in extent is the sandy soil, chiefly to the south of the Trent. There is no chalk, and only a small district is calcareous. The meadows, especially on the banks of the Trent, are most rich and luxuriant; and, though on some spots there is much inert peat, yet, when it is properly drained, it becomes valuable pasture and meadow land. The climate is generally raw and moist: the rain that falls on an average of several years is about thirty-six inches. The quantity of snow, in the winter on the moorlands, is very great, which may contribute to the general coldness of the district.

The Trent, the third river in England, is the principal stream of the county. It rises at Newpool on the confines of Cheshire, and enters Derbyshire below Burton, after having formed a junction with the Dove. Through the whole of its course in this county, it is a clear and rather rapid stream. The Dove is celebrated for the picturesque scenery through which it flows. In its course it receives the Manifold and the Hamps, two streams which are lost in subterraneous channels, but again emerge at the distance of some miles, and rejoin it. The smaller rivers are the Tame, the Blythe, the Sow, and the Penk, all of which empty themselves into the Trent. No part of Great Britain is so intersected with navigable canals as Staffordshire, and in no county have their beneficial effects been so extensively experienced. The Grand Trunk was planned and executed by Mr. Brindley, the most eminent engineer that ever exerted talent in this peculiar branch of inland navigation. This canal is about ninety-one miles in length. The fall of water to the north is 326 feet, and to the south 316 feet. It is twenty-nine feet wide at the top, and about four feet deep. It unites by navigation the internal trade of the great marts of London, Liverpool, Hull, and Bristol. The branches that extend from it in every direction are very numerous, and serve to connect the great shipping ports with all those districts, in the centre of the kingdom, which produce those heavy commodities of which the weight would make them almost worthless without the means of cheap conveyance to distant markets.

That great work, the railroad from Liverpool to Birmingham, has been completed. In proceeding northward it enters this county about a mile from Birmingham, and continues in it for the distance of forty-five miles, when it enters Cheshire. The whole distance of ninety-seven miles is commonly performed in four hours and a half, including stoppages. The towns which, though not on the immediate line of the road, are in communication with it, and at only a few miles distance, are, in this county, West Bromwich, Walsall, Wolverhampton, Stafford, Stone, Eccleshall, Uttoxeter, Newcastle-under-Lyne, Stoke-upon-Trent, and the Potteries. After passing through Cheshire and entering Lancashire, it separates into two branches at Newton, the right proceeding to Manchester, and the left to Liverpool, at the distance of ten miles from each of these towns.

The chief mineral productions of the county are iron and coal, and these are so copious that they appear to be almost inexhaustible. Upwards of 50,000 acres have been already ascertained to have beneath them beds of coal; and notwithstanding the length of time, and the extent to which they have been worked, it is calculated that not one-tenth

Stafford-
shire.

of their contents has been yet consumed. The strata of this mineral, in the mines already worked, vary in thickness from twenty-four to thirty-six feet. Every portion of the coal district abounds in iron ore; and the strata of that mineral are generally found beneath a stratum of coal. Copper and lead are also raised, but not to an extent nearly approaching that of iron. Limestone, freestone, alabaster, marble, ochre, gypsum, and clays of various descriptions, applicable to the purposes of the potteries, are most abundantly extracted from the bowels of the earth. Though salt springs are both copious and richly impregnated with that mineral, no rock salt has yet been discovered; but it is supposed there are some abundant repositories of it beneath the surface.

The relative proportion of the employment of the several families, shows the great preponderance of manufacturing labour in this county. The whole of the southern part is occupied in the different working of metals. Wolverhampton is the chief seat of the manufacture of locks, keys, hinges, bolts, and the heavier kinds of iron ware. Walsall furnishes buckles, bitts, stirrups, spurs, and all the kinds of hardware used by saddlers. Wednesbury supplies guns, iron axle-trees, saws, trowels, hammers, edge tools, and cast-iron work of every kind. Almost all the villages in the vicinity of these towns contribute in a greater or less degree to supply part of the work for which the town nearest to them is the great mart.

The northern part of Staffordshire is celebrated for the excellence of its earthenware, with which it supplies the consumption of the greater portion of the civilized world. The great extension of this manufacture has been owing to the scientific skill and persevering energy of one distinguished individual, the late Mr. Wedgwood; whose combinations of the different earths, and study of the arts of design, have given a value to that which before was almost worthless, and increased to a most wonderful extent the wealth of his neighbourhood, and the number and comfort of its inhabitants. By means of the canals, the pipe-clay from Dorsetshire and Devonshire, and the flints from Kent, are brought to the spots where the clays and coal abound; and the finished goods, by the same means, are conveyed to the great shipping ports, from whence they are distributed to all parts of the globe. Salt is made from natural springs at Shirleyweck, and of late, at Lord Talbot's works at Ingestrie, to such an extent as to supply all those parts of the middle of the kingdom which are not in more close connection with the refineries of Northwich or Droitwich. There are some respectable establishments at Cheadle for making brass and copper goods. Shoes are manufactured on an extensive scale at Stafford and at Newcastle. At Tamworth are great works for printing calicoes. Burton has ale-breweries of great celebrity, with manufactures of hats, and of several kinds of cotton goods. At Leek there are large and flourishing establishments for ribbons, handkerchiefs, ferrets, galloons, and other kinds of silk goods.

In order to exhibit the proportion of employment in the several branches of industry, we extract the notices from the returns under the population of 11 Geo. IV., cap. 30. "Eastward of West Bromwich, 1000 males are employed in the further preparation of iron for the forges and workshops; 2200 are employed at Tipton, 1200 at Walsall, 740 at Willenhall, 157 at Wednesfield, 444 at Wednesbury, and 200 at Rowley Regis, in making guns and other fire-arms, gas-tubes, chains, spades, locks and keys, &c. &c. &c.; and in producing the more various and complex aids of human industry, which are comprehended under the name of machinery. At the villages of Smithwick and Handworth, near to Birmingham, 150 men are similarly occupied. Wolverhampton contains 2000 men, who, in addition to articles before mentioned, are employed in making domestic fire-irons, and turned and jappanned iron-

Stafford-ware. Sedgley contains 500, and Kingswinford 200 manufacturers of the same kinds of goods. At Tettenhall sixty men, and at Brewood 190 men are employed, with 500 in villages, in the less refined manufacture of stock-locks; and in most of the places here enumerated, the more domestic manufacture of iron nails, furnishes employment to 2500 men, and to a part of their families.

"The other great manufacturing branch of the county, the pottery, is spread over the vicinity of Newcastle; in which the town of Burslem contains 900 men and their families; Shelton, a larger number; Longtown and Lane End, nearly 1000; Parkhall, 700; Handley, 360; Fenton Calvert, 300; and Sneyd, 150; all within the parish of Stoke-upon-Trent. In the town of Stafford 800 men are employed in making shoes, and in the district of the potteries is some cotton trade. The working of the coal mines alone, is a great source of occupation for men and machinery."

The cultivated lands of this county are nearly all enclosed by good hedges, chiefly of the white thorn, in fields of from twenty to thirty acres. The general rotation of crops in the clayey soil is, 1st, fallow; 2d, wheat; 3d, oats, after which they are laid down with clover, trefoil, and rye-grass, for two or more years. On breaking up an old sward, the usual course is, 1st, oats; 2d, fallow; 3d, wheat; 4th, oats; and then the grasses. On the more friable soils the rotation is, 1st, fallow; 2d, wheat; 3d, beans, or pease; 4th, oats, and then the grasses. On the light soil, the Norfolk system of turnips, barley, clover, and then wheat, is most commonly followed.

The black cattle are generally of the long-horned breed, and of late years have been much improved by the spirited exertions of some distinguished individuals. The sheep are of different races; the new Leicesters are said to be the most predominant. About Cannock and Sutton Coldfield they have a breed much resembling the South Downs. On the moorland there is a breed with white faces, without horns, and long combing wool. The county is well stocked with timber, especially on the estates of some of the great proprietors. The lands in an unimproved state are still estimated to amount to nearly one-tenth part of the whole county.

The Roman antiquities are the Watling Street and the Ichnield roads, which pass through the county; and the remains of ancient stations or encampments. Here the Saxons have left few remains that merit particular attention.

This county gives titles to the following peers: that of marquis of Stafford, to the eldest son of the duke of Sutherland; those of earls to Ferrers, Talbot, Harrowby, and Lichfield. For parliamentary purposes, the county has been formed into two divisions, distinguished by their position as North and South; each of which elects two members to the House of Commons. The election for the northern division is held at Stafford; and the other polling places are Leek, Newcastle-under-Lyne, Cheadle and Abbots Bromley. The election for the southern division is held at Walsall; and the other polling places are Lichfield, Wolverhampton, Penkridge, and Kingswinford. By the Reform Bill, the towns of Wolverhampton and Stoke-upon-Trent have been entitled to elect two members each, and Walsall to elect one.

The most remarkable noblemen and gentlemen's seats are the following:—Trentham, duke of Sutherland; Beaudesert, marquis of Anglesea; Ingestrie, earl Talbot; Sandon, earl of Harrowby; Sandwell, earl of Dartmouth; Emville, earl of Stamford; Shugborough, earl of Lichfield; Wrothesley, Sir J. Wrothesley; Wolsely Hall, Sir Charles Wolsely; Tixall, Sir T. H. Clifford; Etruria, Josiah Wedgewood, Esq.; Weston, earl of Bradford.

See Plott's History of Staffordshire; Pitt's Agricultu-

ral Survey of Staffordshire; Aikin's History of Manchester; Shaw's History and Antiquities of Staffordshire; Jackson's History of Lichfield; Beauties of England and Wales.

STAGE, in the modern drama, the place of action and representation, included between the pit and the scenes, and answering to the proscenium or pulpitum of the ancients. See PLAYHOUSE and THEATRE.

STAHL, GEORGE ERNEST, an eminent German chemist, was born at Anspach, on the 21st of October 1660, and chosen professor of medicine at Halle, when a university was founded in that city in 1694. The excellency of his lectures while he filled that chair, the importance of his various publications, and his extensive practice, soon raised his reputation to a very great height. He received an invitation to Berlin in 1716, which having accepted, he was made counselor of state and physician to the king. He died in 1734, in the seventy-fifth year of his age. Stahl is without doubt one of the greatest men of which the annals of medicine can boast: his name marks the commencement of a new and more illustrious era in chemistry. He was the author of the doctrine of phlogiston, which, though now completely overturned by the discoveries of Lavoisier and others, was not without its use, as it served to combine the scattered fragments of former chemists into a system, and as it gave rise to more accurate experiments and a more scientific view of the subject, to which many of the subsequent discoveries were owing. This theory maintained its ground for more than half a century, and was received and supported by some of the most eminent men which Europe has produced; a sufficient proof of the ingenuity and the abilities of its author. He was the author also of a theory of medicine, founded upon the notions which he entertained of the absolute dominion of mind over body; in consequence of which he affirmed, that every muscular action is a voluntary act of the mind, whether attended with consciousness or not. This theory he and his followers carried a great deal too far; but the advices at least which he gives to attend to the state of the mind of the patient, are worthy of the attention of physicians.

"Stahl," says Dr. Cullen, "has explicitly founded his system on the supposition, that the power of nature, so much talked of, is entirely in the rational soul. He supposes that, upon many occasions, the soul acts independently of the state of the body; and that, without any physical necessity arising from that state, the soul, purely in consequence of its intelligence, perceiving the tendency of noxious powers threatening, or of disorders anyways arising in the system, immediately excites such motions in the body as are suited to obviate the hurtful or pernicious consequences which might otherwise take place. Many of my readers may think it was hardly necessary for me to take notice of a system founded upon so fanciful a hypothesis; but there is often so much seeming appearance of intelligence and design in the operations of the animal economy, that many eminent persons, as Perrault in France, Nichols and Mead in England, Porterfield and Simson in Scotland, and Gaubius in Holland, have very much countenanced the same opinion, and it is therefore certainly entitled to some regard."¹

His principal works are, 1. *Experimenta et Observationes Chymicæ et Physicæ*, Berlin, 1731, 8vo. 2. *Dissertationes Medicæ*. Halle, 2 vols. 4to. 3. *Theoria Medica vera*. 1737, 4to. 4. *Opusculum Chymico-physico-medicum*. 1740, 4to. 5. A Treatise on Sulphur, both Inflammable and Fixed, written in German. 6. *Negotium Otiosum*. Halle, 1720, 4to. It is in this treatise chiefly that he establishes his system concerning the action of the soul upon the body. 7. *Fundamenta Chymicæ Dogmaticæ et Experimentalis*.

Stage,
Stahl.

¹ Cullen's First Lines of the Practice of Physic, vol. i. p. 12.

Staindrop Nürnberg, 1747, 3 vols. 4to. 8. A Treatise on Salts, written in German.

||
Stamina.

STAINDROP, a town of Darlington ward in the county of Durham, 246 miles from London. It had once a market, which of late years has been disused. Near to it is the splendid mansion of the Duke of Cleveland, Raby Castle, built by John de Neville in 1378. The inhabitants of the town were, in 1801, 1156; in 1811, 1087; in 1821, 1273; and in 1831, 1478.

STAINES, a town in the hundred of Spelthorne and county of Middlesex, seventeen miles from London. It is on the left bank of the Thames, over which a stone bridge has recently been erected. Just above the bridge is the termination of the boundary of the London corporation on the river, marked by a stone, formerly by stones, from which the town takes its name. There is a good corn market on Friday, and several posting houses. The inhabitants were, in 1801, 1750; in 1811, 2042; in 1821, 1957; and in 1831, 2486.

STAIRCASE, in *Architecture*, an ascent inclosed between walls, or a balustrade consisting of stairs or steps, with landing places and rails, serving to make a communication between the several storeys of a house. See **ARCHITECTURE**.

STALACTITES, in *Mineralogy*, crystalline spars formed into oblong, conical, round, or irregular bodies, composed of various crusts, and usually found hanging in form of icicles from the roofs of grottoes, &c.

STALBRIDGE, a town of the hundred of Brownshall and the division of Sherborne, in the county of Dorset, 112 miles from London. It has some trade in making stockings, and much good stone is found near to it. The market is on Tuesday, but thinly attended. The inhabitants were, in 1801, 1254; in 1811, 1421; in 1821, 1571; and in 1831, 1773.

STALE, among sportsmen, a living fowl put in a place to allure and bring others where they may be taken. For want of these, a bird shot, his entrails taken out, and dried in an oven in his feathers, with a stick thrust through to keep it in a convenient posture, may serve as well as a live fowl.

STAMFORD, a town of Lincolnshire, in the hundreds of Ness and of Kesteven. It is eighty-five miles from London, on the river Willand, which divides Lincolnshire from Northamptonshire; and one of the parishes of the town, St. Martin's, is in the latter county, and called the out-parish. There are five parish churches, several of which have lofty spires. Two of them are so close together, as to resemble one building. St. Martin's church contains some curious ancient monuments. In that parish stands Burleigh Hall, the magnificent residence of the marquis of Exeter. This town was in former times a more extensive place than it is at present, and contained fourteen churches, besides many religious houses; but it suffered severely by the wars between the houses of York and Lancaster, and has never recovered from those ravages. It is by no means well built, though of late its appearance has been improved. Being in a rich district, it has good markets on Monday and Friday, and several fairs. The population was, in 1801, 4012; in 1811, 4582; in 1821, 5050; and in 1831, 5837.

STAMINA, in *Botany*, are those upright filaments which, on opening a flower, we find within the corolla surrounding the pistillum. According to Linnæus, they are the male organs of generation, whose office it is to prepare the pollen. Each stamen consists of two distinct parts, viz. the filamentum and the anthera.

STAMINA, in the animal body, are defined to be those simple original parts which existed first in the embryo or even in the seed; and by whose distinction, augmentation, and accretion by additional juices, the animal body at its utmost bulk is supposed to be formed.

STAMPHALIA, one of the islands of Greece, in the Archipelago, about twenty-seven square miles in extent. The surface consists of a single bare mountain, from which numerous springs issue, that render the lower parts capable of cultivation, and some spots are highly fertile. It contains about 800 inhabitants, who raise sufficient barley, wine, and fruit, for their consumption, and a large quantity of onions, which is the principal source of their trade. In a small island close to it are the remains of an ancient temple of Apollo. The number of partridges is so considerable, that to prevent their increase, from 10,000 to 12,000 of their eggs are taken every Easter. In the island there is a small town of the same name. Lat. 36.35. Long. 28.37.E.

STANCHIONS, a sort of small pillars of wood or iron, used for various purposes in a ship, as to support the decks, the quarter-rails, the nettings, the awnings, &c. The first of those are two ranges of small columns fixed under the beams, throughout the ship's length between decks; one range being on the starboard and the other on the larboard side of the hatchways. They are chiefly intended to support the weight of the artillery.

STANDON, a town in the hundred of Braughen and county of Hertford, twenty-seven miles from London. It is on the river Kib, on the ancient Roman road, called Ermine Street. The parish church has an ancient altar, raised nearly ten feet above the level of the floor. On Friday there is a market, tolerably well attended. The population was, in 1801, 1846; in 1811, 1889; in 1821, 2135; and in 1831, 2272.

STANDRA, a village of Asiatic Turkey, on the western coast of Anatolia. Long. 27. 18. E. Lat. 36. 54. W.

STANHOPE, **PHILIP DORMER**, the fourth **EARL OF CHESTERFIELD**, was born at London, on the 22d of September 1694. He was the son of Philip, the third earl, by his wife, Lady Elizabeth Savile, daughter of George, marquis of Halifax. At the age of eighteen he was sent to Trinity Hall, Cambridge, where he studied assiduously, and, according to his own account, became an absolute pedant. In 1714 he quitted the university, and travelled on the continent, where a familiarity with good company soon convinced him he was totally mistaken in almost all his notions; and an attentive study of the air, manner, and address of people of fashion, soon polished a man whose prominent desire was to please, and who, as it afterwards appeared, valued exterior accomplishments beyond any other human acquirement. While Lord Stanhope, he obtained an early seat in parliament; and in 1722, succeeded to his father's estate and titles. In 1728, and in 1745, he was appointed ambassador extraordinary and plenipotentiary to Holland. This high character he supported with the greatest dignity, serving his own country, and gaining the esteem of the States-General. Upon his return from Holland, he was sent as lord-lieutenant of Ireland; and during his administration there, gave general satisfaction to all parties. He left Dublin in 1746, and in October succeeded the earl of Harrington as secretary of state, in which post he officiated until February 6, 1748. In 1752, being seized with a deafness which incapacitated him for the pleasures of society, he from that time led a private and retired life, amusing himself with books and his pen; in particular, he engaged largely as a volunteer in a periodical miscellaneous paper called *The World*, in which his contributions have a distinguished degree of excellence. He died on the 24th of March 1773, leaving a character for wit and abilities that had few equals. He distinguished himself by his eloquence in parliament on many important occasions, of which we have a characteristic instance of his own relating. He was an active promoter of the bill for altering the style; and on this occasion, as he himself writes in one of his letters to his son, he made so eloquent a speech in the house, that every one was pleased, and said he had made the whole very clear to them, "when,"

Stamphalia
||
Stanhope.

Stanhope. says he, "God knows, I had not even attempted it. I could just as soon have talked Celtic or Slavonian to them, as astronomy; and they would have understood me full as well."

Lord Macclesfield, who was considered as a great mathematician, and who had a principal hand in framing the bill, spoke afterwards, with all the clearness that a thorough knowledge of the subject could dictate; but not having a flow of words equal to Lord Chesterfield, the latter gained the applause which was more justly due to the former. The high character which Lord Chesterfield supported during life, received no small injury soon after his death, from a fuller display of it by his own hand. He left no issue by his lady, Melosina de Schulenburg, countess of Walsingham; but he had a natural son, Philip Stanhope, Esq., whose education was for many years a close object of his attention, and who was afterward envoy extraordinary at the court of Dresden, but died before him. After Lord Chesterfield's death, Mr. Stanhope's widow published a series of letters, written by the father to the son, filled with instructions suitable to the different gradations of the young man's life to whom they were addressed. These letters contain many fine observations on mankind, and rules of conduct; but it is observable that he lays a greater stress on exterior accomplishments and address than on intellectual qualifications and sincerity; and allows a much greater latitude to fashionable pleasures than good morals will justify. These Letters to his Son, so discreditable to the memory of the writer, appeared in 1774, in 2 vols. 4to. This publication was followed by a collection of his Miscellaneous Works, 1777, 2 vols. 4to. A third volume was added in 1778; but his lordship's works do not appear to have attracted much attention.

STANHOPE, CHARLES, Earl Stanhope, born in 1753, was the eldest son of Philip, the second earl, a man equally remarkable for his mathematical talents, and his liberal political opinions. The subject of this notice succeeded to the peerage in 1786, and died in 1816. By his first marriage he became the brother-in-law of Pitt; and on the mother's side he was closely allied to the Scottish earls of Haddington. This eccentric but public-spirited and most inventive man, while he divided his attention among a variety of inquiries, sufficient to have prevented excellence in any, had the rare merit of excelling in several most important pursuits, while in more than one he has bequeathed to the world discoveries that have proved most extensively useful. In politics he was a decided Whig, an assertor of religious toleration, and of non-intervention in the internal affairs of foreign states. Sometimes, however, he carried out the principles of his party with a boldness which other minds scrupled to follow; and in the latter years of his parliamentary life, Earl Stanhope used to be called "the minority of one." His political works were a refutation of Price's scheme of the sinking fund, an answer to one of Burke's invectives on the French Revolution, and an essay on juries. But his inventions in mechanical science are those by which he has secured the gratitude of posterity. They are too many to be here so much as completely enumerated. The principal of them, the Stanhope press, has been described in our article PRINTING, where notice has also been taken of his exertions for improving the process of stereotype. He was an early student of Franklin's theory of electricity, to which he contributed several valuable observations. Another of his most useful inventions was one for improving the locks of canals; and more curious ones were his two calculating machines, one of which performed addition and subtraction, the other multiplication and division.

STANHOPE, George, an eminent divine, was born at Hertishorn in Derbyshire, in the year 1660. His father was rector of that parish, vicar of St. Margaret's at Leicester, and chaplain to the earls of Chesterfield and Clare. His grandfather, Dr. George Stanhope, was chaplain to James I.

VOL. XX.

and Charles I.; had the chancellorship of York, where he Stanhope. was also a canon residentiary, held a prebend, and was rector of Weldrake in that county. For his loyalty he was driven from his home with eleven children, and died in 1664. The son was sent to school, first at Uppingham in Rutland, then at Leicester; he was afterwards removed to Eton, and thence chosen to King's College in Cambridge, in the place of W. Cleaver. He took the degree of A. B. in 1681, and of A. M. in 1685; was elected one of the syndics for the university of Cambridge, in the business of Alban Francis, 1687; minister of Quoi near Cambridge, and vice-proctor, 1688. He was that year preferred to the rectory of Tring in Hertfordshire, which after some time he quitted. In 1689 he was presented to the vicarage of Lewisham in Kent by Lord Dartmouth, to whom he had been chaplain, as well as tutor to his son. He was also appointed chaplain to King William and Queen Mary, and continued to enjoy that honour under Queen Anne. He commenced D. D. July 5, 1697, performing all the exercises required to that degree publicly and with great applause. He was made vicar of Deptford in 1703; succeeded Dr. Hooper as dean of Canterbury the same year; and was thrice chosen prolocutor of the lower house of convocation. His uncommon diligence and industry, assisted by his excellent parts, enriched him with a large stock of polite, solid, and useful learning. His discourses from the pulpit were equally pleasing and profitable; a beautiful intermixture of the clearest reasoning with the purest diction, attended with all the graces of a just elocution. In him were happily united the good Christian, the solid divine, and the fine gentleman. His conversation was polite and delicate, grave without preciseness, facetious without levity. His piety was real and rational, his charity great and universal, fruitful in acts of mercy and in all good works. He died March 18, 1728, aged sixty-eight years; and was buried in the chancel of the church at Lewisham. The dean was twice married; first to Olivia Cotton, by whom he had one son and four daughters. His second lady, who was sister to Sir Charles Wager, survived him, dying October 1, 1738, aged about fifty-four. One of the dean's daughters was married to a son of Bishop Burnet. Dr. Moore, bishop of Ely, died the day before Queen Anne; who, it has been said, designed the dean for that see when it should become vacant. "The late Dean of Canterbury," says Dr. Felton, "is excellent in the whole. His thoughts and reasoning are bright and solid. His style is just, both for the purity of the language and for the strength and beauty of expression; but the periods are formed in so peculiar an order of the words, that it was an observation, nobody could pronounce them with the same grace and advantage as himself." His writings, which are considered as a treasure of piety and devotion, are, A Paraphrase and Comment upon the Epistles and Gospels. 1705, 4 vols. 8vo. Sermons at Boyle's Lectures. 1706, 4to. Fifteen Sermons. 1700, 8vo. Twelve Sermons on Several Occasions. 1727, 8vo. A Translation of Thomas à Kempis. 1696, 8vo. Epictetus's Morals, with Simplicius's Comment, and the Life of Epictetus. 1700, 8vo. Parson's Christian Directory. 1716, 8vo. Rochefoucault's Maxims. 1706, 8vo. A Funeral Sermon on Mr. Richard Sare, bookseller, 1724; two editions 4to. Twenty Sermons, published singly between the years 1692 and 1724. Private Prayers for every Day in the Week, and for the several Parts of each Day; translated from the Greek Devotions of Bishop Andrews, with Additions, 1730. In his translations, it is well known, Dr. Stanhope did not confine himself to a strict and literal version; he took the liberty of paraphrasing, explaining, and improving upon his author, as will evidently appear (not to mention any other work) by the slightest perusal of St. Augustin's Meditations, and the Devotions of Bishop Andrews.

STANISLAS LECKZINSKI, king of Poland, was born at

4 B

Stanislas. Lemberg, the capital of Red Russia, on the 20th of October 1677. His father was a Polish nobleman, distinguished by his rank and the important offices which he held, but still more by his firmness and courage. In 1704 Stanislas was sent ambassador, by the Assembly of Warsaw, to Charles XII. of Sweden, who had conquered Poland. He was at that time twenty-seven years old, was general of Great Poland, and had been ambassador extraordinary to the Grand Signior in 1699. Charles was so delighted with the frankness and sincerity of his deportment, and with the firmness and sweetness which appeared in his countenance, that he offered him the crown of Poland, and ordered him to be crowned at Warsaw in 1705. He accompanied Charles into Saxony, where a treaty was concluded with King Augustus in 1705, by which that prince resigned the crown, and acknowledged Stanislas king of Poland. The new monarch remained in Saxony with Charles till 1707, when they returned into Poland and attacked the Russians, who were obliged to evacuate that kingdom in 1708. But Charles being defeated by Peter the Great in 1709, Augustus returned into Poland, and being assisted by a Russian army, obliged Stanislas to retire first into Sweden, and afterwards into Turkey. Soon after, he took up his residence at Weissenburg, a town in Alsace. Augustus dispatched Sum his envoy to France to complain of this; but the duke of Orleans, who was then regent, returned this answer: "Tell your king, that France has always been the asylum of unhappy princes." Stanislas lived in obscurity till 1725, when Louis XV. espoused the princess Mary his daughter. Upon the death of King Augustus in 1733, he returned to Poland, in hopes of remounting the throne of that kingdom. A large party declared for him; but his competitor, the young elector of Saxony, being supported by the emperor Charles VI. and the empress of Russia, was declared king, though the majority was against him. Dantzic, to which Stanislas had retired, was quickly taken, and with great difficulty the unfortunate prince made his escape in disguise, after hearing that the Russians had set a price upon his head. In 1736, when peace was concluded between the emperor and France, it was agreed that Stanislas should abdicate the throne, but that he should be acknowledged king of Poland and grand duke of Lithuania, and continue to bear these titles during life; that all his effects and those of the queen his spouse should be restored; that an amnesty should be declared in Poland for all that was past, and that every person should be restored to his possessions, rights, and privileges; that the elector of Saxony should be acknowledged king of Poland by all the powers who acceded to the treaty; that Stanislas should be put in peaceable possession of the duchies of Lorraine and Bar, but that immediately after his death those duchies should be united for ever to the crown of France. In Lorraine Stanislas succeeded a race of princes, who were beloved and regretted; and his subjects found their ancient sovereigns revived in him. He then tasted the pleasure which he had so long desired, the pleasure of making men happy. He assisted his new subjects; he embellished Nancy and Luneville; he formed useful establishments; he founded colleges, and built hospitals. He was engaged in these noble employments, when an accident occasioned his death. His nightgown caught fire, and burnt him so severely before it could be extinguished, that he was seized with a fever, and died the 23d of February 1766. He was a protector of the arts and sciences. He wrote several works of philosophy, politics, and morality, which were collected and published at Paris in 1763, in 4 vols. 8vo., under the title of "*Œuvres du Philosophe bienfaisant.*" An octavo volume, ornamented with engravings, was published in 1825, under the title of "*Œuvres choisies de Stanislas, Roi de Pologne, Duc de Lorraine et de Bar;*" to which an historical notice was prefixed by Madame de Saint-Ouen.

STANISLAWOW, a circle of the Austrian principality of Galicia, extending over 1495 square miles. It comprises five cities, thirteen market towns, and 264 villages, with 186,400 inhabitants. The capital is the city of the same name, between two branches of the river Wistrice. It is well built, and contains Catholic, Greek, and Armenian churches, with 370 houses, and 6880 inhabitants. The Jews and Armenians are the principal traders. Lat. 43. 56. Long. 24. 38. E.

STANLEY, THOMAS, a very learned writer, was the son of Sir Thomas Stanley of Laytonstone in Essex, and Cumberlow in Hertfordshire, by his second wife Mary, the daughter of Sir William Hammond of St. Alban's-court. He was descended from a natural son of Edward earl of Derby. He was born in the year 1625, and received a domestic education under the tuition of William the son of Edward Fairfax, the well-known translator of Tasso. In 1639, he became a fellow-commoner of Pembroke Hall, Cambridge, where he distinguished himself by his progress in classical learning. After having travelled on the continent, he resided for some time in the Middle Temple. Here he lived on terms of particular intimacy with his cousin Edward, afterwards Sir Edward Sherburne, who cultivated similar studies, and who dedicated a volume of Poems to this learned kinsman. Stanley published Poems and Translations in 1649, 8vo. They were reprinted, with additions, in 1651. But his principal work was his "*History of Philosophy, containing the Lives, Opinions, Actions, and Discourses of the Philosophers of every Sect.*" Of the original edition, printed in folio, the first part appeared in 1655, and the third in 1660. The work is dedicated to his uncle-in-law, Sir John Marsham, author of the *Canon Chronicus*, who first suggested the undertaking. There are four editions of the History, the last and best being that of 1743, 4to. The author has displayed solid as well as extensive erudition, but his valuable materials are not disposed to the best advantage. The reputation of his work extended to the continent; and a Latin translation of it by Olearius was published at Leipzig, in quarto, in the year 1711. The part relating to the history of oriental philosophy had been translated into the same language by Le Clerc, and published at Amsterdam in 1690, with a dedication to Bishop Burnet. This version he afterwards inserted in the second volume of his "*Opera Philosophica.*" Stanley next prepared his elaborate and valuable edition of *Æschylus*. Lond. 1663, fol. Some copies of the same impression bear the date of 1664. This edition, which includes the fragments and the Greek scholia, and is accompanied with a commentary and a Latin version, was of great importance when it first appeared; but since the death of the learned editor, so much has been effected by Schütz, Wellauer, and other scholars, that it has lost a great portion of its original value. The best of all possible editions of *Æschylus* has for many years been expected from Hermann; but those who have sufficient means of ascertaining his present views and occupations, have at length begun to despair of its ever making its appearance. It was thought expedient to reprint Stanley's edition, with the commentary, corrected and enlarged from his papers preserved in the university library at Cambridge. The charge of this edition was committed to a very competent scholar, Samuel Butler, afterwards promoted to the bishopric of Lichfield; who, with the addition of his own annotations, published it at Cambridge in the year 1809, in 4 vols. 4to., and in 8 vols. 8vo. Some notes on Demosthenes, ascribed to Stanley, have recently been published in the ninth volume of Dobson's *Oratores Attici*. He died at his lodgings in Suffolk-street, in the parish of St. Martin's-in-the-Fields, on the 12th of April 1678. He had married Dorothy, the daughter and co-heiress of Sir James Enyon of Flower in Northamptonshire, Bart. He had a son, who bore his own name, and, like himself, was educated at Pem-

Stanisla-
wow,
Stanley.

Stannaries
||
Star.

broke Hall. At a very early age, he published "Aelian's Various Histories, translated into English." Lond. 1665, 8vo.

STANNARIES, the mines and works where tin is dug and purified; as in Cornwall, Devonshire, &c.

STANNARY COURTS, in Devonshire and Cornwall, for the administration of justice among the tanners. They are held before the lord-warden and his substitutes, by virtue of a privilege granted to the workers in the tin-mines there, to sue and be sued only in their own courts, that they may not be drawn from their business, which is highly profitable to the public, by attending their law-suits in other courts.

STANOVOL, a chain of mountains in Asiatic Russia, forming a part of the great northern chain which crosses the breadth of that continent. It is of considerable height, and continues uninterrupted, though with some diminution of magnitude, to Cape Tchontchi, at the north-eastern extremity of Asia; and the Aleutian and Fox Islands may be considered as in some degree a continuation of it. This chain turns to the north near the source of the Aldane, whence it runs parallel to the eastern sea or gulf of Okhotsk, a narrow plain only intervening. Granite and porphyry are the chief materials of which these mountains consist, though there are some of green jasper.

STANSTEAD, a town in the hundred of Braughen, and county of Hertford, sixteen miles from London. It stands in a valley near the river Lea, two miles from Hoddesdon. In this parish is the Rye-house, remarkable for the supposed plot in the reign of Charles the Second, for the assassination of that monarch. The population was, in 1801, 861; in 1811, 832; in 1821, 950; and in 1831, 966.

STANSTEAD-MOUNTFITCHET, a small town in the county of Essex and hundred of Uttlesford, thirty-four miles from London. It derives its name from an ancient castle, built on an artificial mount about a quarter of a mile from the church, some relics of which are still visible. The hamlet of Bentfield is comprehended in the parish, and their united population was, in 1801, 1285; in 1811, 1334; in 1821, 1518; and in 1831, 1560.

STANZA, in *Poetry*, a number of lines regularly adjusted to each other; so much of a poem as contains every variation of measure or relation of rhyme used in that poem.

STAPLE primarily signifies a public place or market, whither merchants, &c. are obliged to bring their goods to be bought by the people. The merchants of England were formerly obliged to carry their wool, cloth, lead, and other like staple commodities of this realm, in order to expose them by wholesale; and these staples were appointed to be constantly kept at York, Lincoln, Newcastle-upon-Tyne, Norwich, Westminster, Canterbury, Chichester, Winchester, Exeter, and Bristol; in each of which a public mart was appointed to be kept, and each of them had a court of the mayor of the staple, for deciding differences, held according to the law-merchant, in a summary way.

STAR, in *Astronomy*, a general name for all the heavenly bodies, which, like so many brilliant studs, are dispersed throughout the whole heavens. The stars are distinguished, from the phenomena of their motion, &c., into fixed, and erratic or wandering stars. These last are again distinguished into the greater luminaries, viz. the sun and moon; the planets, or wandering stars, properly so called, and the comets; which have been all fully considered and explained under the article ASTRONOMY. As to the fixed stars, they are so called, because they seem to be fixed, or perfectly at rest, and consequently appear always at the same distance from each other.

Falling STARS, in *Meteorology*, fiery meteors which dart through the sky in the form of a star.

STAR, in *Fortification*, denotes a small fort, having five or more points, or salient and re-entering angles, flanking one another, and their faces ninety or a hundred feet long.

STAR-CHAMBER, Court of, (*Camera Stellata*), a famous, or rather infamous, English tribunal, said to have been so called either from a Saxon word signifying to *steer* or govern; or from its punishing the *crimen stellionatus*, or cozenage; or because the room in which it sat, the old council-chamber of the palace of Westminster, was full of windows; or, (to which Sir Edward Coke, 4 Inst. 66. accedes), because *haply* the roof thereof was at the first garnished with gilded stars. This was a court of very ancient original; but new-modelled by statutes 3 Henry VII. c. 1, and 21 Henry VIII. c. 20, consisting of divers lords spiritual and temporal, being privy-councillors, together with two judges of the courts of common law, without the intervention of any jury. Their jurisdiction extended legally over riots, perjury, misbehaviour of sheriffs, and other notorious misdemeanours, contrary to the laws of the land. Yet this was afterwards, as Lord Clarendon informs us, stretched "to the asserting of all proclamations and orders of state; to the vindicating of illegal commissions and grants of monopolies; holding for honourable that which pleased, and for just that which profited; and becoming both a court of law to determine civil rights, and a court of revenue to enrich the treasury: the council-table by proclamations enjoining to the people that which was not enjoined by the laws, and prohibiting that which was not prohibited; and the star-chamber, which consisted of the same persons in different rooms, censuring the breach and disobedience to those proclamations by very great fines, imprisonments, and corporal severities: so that any disrespect to any acts of state, or to the persons of statesmen, was in no time more penal, and the foundations of right never more in danger to be destroyed." For these reasons, it was finally abolished by statute 16 Car. I. c. 10, to the general joy of the whole nation.

STAR-BOARD, the right side of the ship when the eye of the spectator is directed forward.

STAR-shot, a gelatinous substance frequently found in fields, and supposed by the vulgar to have been produced from the meteor called a *falling-star*; but, in reality, it is the half-digested food of herons, seamews, and the like birds; for these birds have been found, when newly shot, to disgorge a substance of the same kind.

STARAJA-RUSSA, a city of Russia in the province of Moscow and government of Novogorod, the capital of a circle of the same name. It is 206 miles from Petersburg, on the river Polesta. It is an ill-built place, containing 1048 houses, many of them of wood, and 6200 inhabitants. There is a copious brine spring, from which about 100,000 bushels of culinary salt are annually made, and this is the chief trade of the place. Lat. 57. 51. Long. 32. 54. 25. E.

STARCH, a fecula or sediment, found at the bottom of vessels in which wheat has been steeped in water. Of this fecula, after separating the bran from it, by passing it through sieves, they form a kind of loaves, which being dried in the sun or an oven, is afterwards cut into little pieces, and so sold. The best starch is white, soft, and friable, and easily broken into powder. Such as require fine starch, do not content themselves, like the starchmen, with refuse wheat, but use the finest grain. The process is as follows. The grain, being well cleaned, is left to ferment in vessels full of water, which they expose to the sun while in its greatest heat; changing the water twice a-day, for the space of eight or twelve days, according to the season. When the grain bursts easily under the finger, they judge it sufficiently fermented. The fermentation being perfected, and the grain thus softened, it is put, handful by handful, into a canvass-bag, to separate the flour from the husks; which is done by rubbing and beating it on a plank laid across the mouth of an empty vessel that is to receive the flour. As the vessels are filled with this liquid flour, there is seen swimming at top a reddish water, which is to be carefully skimmed off

Star-cham-
ber
||
Starch.

Stargard
||
Stark.

from time to time, and clean water is to be put in its place, which, after stirring the whole together, is also to be strained through a cloth or sieve, and what is left behind put into the vessel with new water, and exposed to the sun for some time. As the sediment thickens at the bottom, they drain off the water four or five times, by inclining the vessel, but without passing it through the sieve. What remains at bottom is the starch, which is cut in pieces to be taken out, and is left to dry in the sun. When dry, it is laid up for use.

STARGARD, a city of the Prussian province of Pomerania in the government of Stettin, the capital of the circle of Saalzig. It stands on the navigable river Ihna, in a fertile district, is surrounded with walls, and in 1834 contained 9989 inhabitants, who are employed in making linen and woollen goods, hosiery, hats, leather, soap, and tobacco, and in brewing and distillation. It was formerly the capital of Pomerania. Lat. 52. 20. 42. Long. 15. 13. E.

STARITZA, a town of Russia, in the province of Moscow and government of Twer. It is the capital of a circle of the same name, containing seventy-seven parishes, with 83,800 inhabitants. It is 378 miles from Petersburg, and stands on the river Wolga, where the river Staritza joins that stream. It contains six churches, 650 houses, and 3860 inhabitants, whose chief trade is in hemp sent to Petersburg, and in making shoes and gloves. Lat. 56. 48. Long. 35. 22. E.

STARK, WILLIAM, was born at Manchester in the month of July 1740; but the family from which he sprang was Scottish, and respectable for its antiquity. One of his uncles, John Stark, was minister of Lecropt in Perthshire; and it was under the care of this gentleman that he received the rudiments of his education, which, when we consider the character of the master, and reflect on the relation between him and his pupil, we may presume was calculated to store the mind of the latter with those virtuous principles which influenced his conduct through life. From Lecropt young Stark was sent to the university of Glasgow, where, under the tuition of Dr. Smith and Dr. Black, with other eminent masters, he learned the rudiments of science, and acquired that mathematical accuracy, that logical precision, and that contempt of hypotheses, with which he prosecuted all his future studies. Having chosen physic for his profession, he removed from the university of Glasgow to that of Edinburgh, where he was soon distinguished, and honoured with the friendship of the late Dr. Cullen; a man who was not more eminently conspicuous for the superiority of his own genius, than quick-sighted in perceiving, and liberal in encouraging, genius in his pupils. Having finished his studies at Edinburgh, though he took there no degree, Mr. Stark, in the year 1765, went to London, and devoted himself entirely to the study of physic and the elements of surgery; and looking upon anatomy as one of the principal pillars of both these arts, he endeavoured to complete with Dr. Hunter what he had begun with Dr. Monro; and under these two eminent teachers he appears to have acquired a high degree of anatomical knowledge. He likewise entered himself, about this time, a pupil at St. George's hospital; and with what industry he prosecuted this plan, with what success his labours were crowned, may be seen in a series of Clinical and Anatomical Observations, which were made by him during his attendance at the hospital, and were published after his death by his friend Dr. Carmichael Smyth.

In the year 1767 he went to Leyden, where he took the degree of M.D., publishing an inaugural dissertation on the dysentery. On his return to London, he recommenced his studies at the hospital; and when Dr. Black was called to the chemical chair in Edinburgh, which he long filled with so much honour to himself and credit to the university, Dr. Stark was solicited, by several members of the university of Glasgow, to stand as a candidate for their professorship of the theory and practice of physic, rendered vacant by Dr. Black's removal to Edinburgh. This, however, he de-

clined, being influenced by the advice of his English friends, who wished to detain him in London, and having, likewise, some prospects of an appointment in the hospital. In 1769 he commenced a series of experiments on diet, which he was encouraged to undertake by Sir John Pringle and Dr. Franklin, whose friendship he enjoyed, and from whom he received many hints respecting both the plan and its execution. These experiments, or rather the imprudent zeal with which he prosecuted them, proved, in the opinion of his friends, fatal to himself; for he began them on the 12th of July 1769 in perfect health and vigour, and from that day, though his health varied, it was seldom if ever good, till the 23d of February 1770, when he died after suffering much uneasiness.

STARKENBURG, a province of the Grand Duchy of Hesse Darmstadt, in Germany. It is situated on the right bank of the Rhine, in contact with Nassau on the north, with Hesse Casel on the north-east, with Bavaria on the east, with Baden on the south, and on the west with the Darmstadt dominions to the west of the Rhine. It is 1102 square miles in extent, and contains thirty-six cities and towns, and 811 villages, with 273,293 inhabitants in 1834, nearly one half of whom are Lutherans, two-fifths Catholics, and the remainder Calvinists, Menonites, and Jews. The eastern part contains the mountainous forest country called the Odenwald; but the western part is a level and fertile country, well cultivated, and yielding good crops of corn, fruit, potatoes, flax, hemp, and tobacco. It also produces good wine and abundance of cider. The chief occupation, except agriculture, is spinning flax and hemp, and in converting the trees of the forests into woodware. The province is divided into thirty bailiwicks, and the capital is that of the principality, the city of Darmstadt.

STARLINGS, or STERLINGS, the name given to the strong pieces of timber which were driven into the bed of the river to protect the piles, on the top of which were laid the flat beams upon which were built the bases of the stone piers that support the arches of London bridge. In general, starlings are large piles placed on the outside of the foundation of the piers of bridges, to break the force of the water, and to protect the stone work from injury by floating ice. They are otherwise called *jetties*, and their place is often supplied by large stones thrown at random round the piers of bridges, as may be seen at Stirling bridge when the river is low; and as was done by Mr. Smeaton's direction round the piers of the centre arch of London bridge, when it was thought in danger of being undermined by the current.

STATES, or ESTATES, a term applied to several orders or classes of people assembled to consult of matters for the public good.

STATICS, a term which the modern improvements in knowledge have made it necessary to introduce into physico-mathematical science. It was found convenient to distribute the doctrines of universal mechanics into two classes, which required both a different mode of consideration and different principles of reasoning.

Till the time of Archimedes little science of this kind was possessed by the ancients, from whom we have received the first rudiments. His investigation of the centre of gravity, and his theory of the lever, are the foundations of our knowledge of common mechanics; and his theory of the equilibrium of floating bodies contains the greatest part of our hydrostatical knowledge. But it was as yet limited to the simplest cases; and there were some in which Archimedes was ignorant, or was mistaken. The marquis Guido Ubaldi, in 1578, published his theory of mechanics, in which the doctrines of Archimedes were well explained and considerably augmented. Stevinus, the celebrated Dutch engineer, published about twenty years after an excellent system of mechanics, containing the chief principles which now form the science of equilibrium among solid bodies. In particu-

Starken-
burg
||
Statics.

Statics. lar, he gave the theory of inclined planes, which was unknown to the ancients, though it is of the very first importance in almost every machine. He even states in the most express terms the principle afterwards made the foundation of the whole of mechanics, and published as a valuable discovery by Varignon, viz. that three forces, whose directions and intensities are as the sides of a triangle, balance each other. His theory of the pressure of fluids, or hydrostatics, is no less estimable, including every thing that is now received as a leading principle in the science. When we consider the ignorance, even of the most learned of that age, in mechanical or physico-mathematical knowledge, we must consider these performances as the works of a great genius; and we regret that they are so little known, being lost in a crowd of good writings on those subjects which appeared soon after.

Hitherto the attention had been turned entirely to equilibrium, and the circumstances necessary for producing it. Mechanicians indeed saw, that the energy of a machine might be somehow measured by the force which could be opposed or overcome by its intervention: but they did not remark, that the force which prevented its motion, but did no more than prevent it, was an *exact* measure of its energy, because it was in immediate equilibrio with the pressure exerted by that part of the machine with which it was connected. If this opposed force was less, or the force acting at the other extremity of the machine was greater, the mechanicians knew that the machine would move, and that work would be performed; but what would be the rate of its motion or its performance, they hardly pretended to conjecture. They had not studied the action of moving forces, nor conceived what was done when motion was communicated.

The great Galileo opened a new field of speculation in his work on local motion. He there considers a change of motion as the indication and exact and adequate measure of a moving force; and he considers every kind of pressure as competent to the production of such changes. He contented himself with the application of this principle to the motion of bodies by the action of gravity, and gave the theory of projectiles, which remains to this day without change, and only improved by considering the changes which are produced in it by the resistance of the air.

Sir Isaac Newton took up this subject nearly as Galileo had left it. For, if we except the theory of the centrifugal forces arising from rotation, and the theory of pendulums, published by Huygens, hardly any thing had been added to the science of motion. Newton considered the subject in its utmost extent; and in his mathematical principles of natural philosophy he considers every conceivable variation of moving force, and determines the motion resulting from its action. His first application of these doctrines was to explain the celestial motions; and the magnificence of this subject caused it to occupy for a while the whole attention of the mathematicians. But the same work contained propositions equally conducive to the improvement of common mechanics, and to the complete understanding of the mechanical actions of bodies. Philosophers began to make these applications also. They saw that every kind of work which is to be performed by a machine may be considered abstractedly as a retarding force; that the impulse of water or wind, which are employed as moving powers, act by means of pressures which they exert on the impelled point of the machine; and that the machine itself may be considered as an assemblage of bodies moveable in certain limited circumstances, with determined directions and proportions of velocity. From all these considerations resulted a general abstract condition of a body acted on by known powers. And they found, that after all conditions of equilibrium were satisfied, there remains a surplus of moving force. They could now state the motion which will ensue, the new resis-

tance which this will excite, the additional power which this will absorb; and they at last determined a new kind of equilibrium, not thought of by the ancient mechanicians, between the resistance to the machine performing work and the moving power, which exactly balance each other, and is indicated, not by the *rest*, but by the *uniform motion* of the machine. In like manner, the mathematician was enabled to calculate that precise motion of water which would completely absorb, or, in the new language, balance the superiority of pressure by which water is forced through a sluice, a pipe, or canal, with a constant velocity.

Thus the general doctrines of motion came to be considered in two points of view, according as they balanced each other in a state of rest or of uniform motion. These two ways of considering the same subject required both different principles and a different manner of reasoning. The first has been named *statics*, as expressing that rest which is the test of this kind of equilibrium. The second has been called *DYNAMICS* or *UNIVERSAL MECHANICS*, because the different kinds of motion are characteristic of the powers or forces which produce them. A knowledge of both is indispensably necessary for acquiring any useful practical knowledge of machines; and it was ignorance of the doctrines of accelerated and retarded motions which made the progress of practical mechanical knowledge so very slow and imperfect. The mechanics, even of the moderns, before Galileo, went no further than to state the proportion of the power and resistance which would be balanced by the intervention of a given machine, or the proportion of the parts of a machine by which two known forces may balance each other. This view of the matter introduced a principle, which even Galileo considered as a mechanical axiom, viz., that *what is gained in force by means of a machine is exactly compensated by the additional time which it obliges us to employ*. This is false in every instance, and not only prevents improvement in the construction of machines, but leads us into erroneous maxims of construction. The true principles of dynamics teach us, that there is a certain proportion of the machine, dependent on the kind and proportion of the power and resistance, which enables the machine to perform the greatest possible work.

It is highly proper therefore to keep separate these two ways of considering machines, that both may be improved to the utmost, and then to blend them together in every practical discussion.

Statics therefore are preparatory to the proper study of mechanics; but they do not hence derive all their importance. They are the sole foundation of many useful parts of knowledge. This will be best seen by a brief enumeration.

1. They comprehend all the doctrines of the excitement and propagation of pressure through the parts of solid bodies, by which the energies of machines are produced. A pressure is exerted on the impelled point of a machine, such as the float-boards or buckets of a mill-wheel. This excites a pressure at the pivots of its axle, which act on the points of support. This must be understood, both as to direction and intensity, that it may be effectually resisted. A pressure is also excited at the acting tooth of the cog-wheel on the same axle, by which it urges round another wheel, exciting similar pressures on its pivots, and on the acting tooth perhaps of a third wheel. Thus a pressure is ultimately excited in the working point of the machines, perhaps a wiper which lifts a heavy stamper, to let it fall again on some matter to be pounded. Now statics teach us the intensities and direction of all those pressures, and therefore how much remains at the working point of the machine unbalanced by resistance.

2. They comprehend every circumstance which influences the stability of heavy bodies; the investigation and properties of the centre of gravity; the theory of the construction of arches, vaults, and domes; the attitudes of animals.

Statics.

Stationary,
Statistics.

3. The strength of materials, and the principles of construction, so as to make the proper adjustment of strength and strain in every part of a machine, edifice, or structure of any kind. Statics therefore furnish us with what may be called a *theory of carpentry*, and give us proper instructions for framing floors, roofs, centres, &c.

4. Statics comprehend the whole doctrine of the pressure of fluids, whether liquid or aeriform, whether arising from their weight or from any external action. Hence therefore we derive our knowledge of the stability of ships, or their power of maintaining themselves in a position nearly upright, in opposition to the action of the wind on the sails. We learn on what circumstances of figure and stowage this quality depends, and what will augment or diminish it.

STATIONARY, in *Astronomy*, the state of a planet when, to an observer on the earth, it appears for some time to stand still, or remain immovable in the same place in the heavens. For as the planets, to such an observer, have sometimes a progressive motion, and sometimes a retrograde one, there must be some point between the two where they must appear stationary.

STATISTICS. The term statistics naturally suggests the object to which the science applies. It is derived from the word state, or, according to others, the German word *Staat*, signifying a body of men living together in social union; and it comprehends all the details connected with their condition. There cannot be a more interesting subject of speculation than the structure of society; and if we are anxious to trace, by laborious research, the laws of the material world, no less important is it to ascertain the moral laws by which society is upheld, and on which depend the character, condition, and happiness of man. But neither this nor any other branch of philosophy can be explained without a suitable collection of facts. In those sciences which regard merely the properties of matter, experiments can be made at pleasure, and facts abundantly obtained. But we cannot make experiments on society; and we must therefore rely on observation for the facts by which principles are to be illustrated. As the astronomer, in deducing the laws which regulate the solar system, patiently surveys the structure and movements of the heavens, in like manner the political philosopher must watch the progress of society, under all its various aspects of prosperity and decay, of happiness and misery, from the stagnation of trade, from famine, from disease, or any other of the long catalogue of evils to which man is subject. We cannot expound by *a priori* reasonings the wonderful economy of human society; we cannot find our way through those intricate speculations without the light of facts; and hence the importance of this science, which does not consist in reasoning, but in collecting materials for reasoning, which it is the business of the philosopher to arrange under general principles, and thus to place every fact in its just place in the great system of knowledge. Facts are the only true foundation of philosophy. This is the true mode of philosophising by experiment recommended by Bacon, or by observation, which, to the political inquirer, must supply the place of experiment. Those sketches of society which are merely speculative, however ingenious and amusing, carry no conviction to the mind, and may be supported by other theories equally plausible. But no sophistry can shake the solid array of facts, and their legitimate conclusions, of which all valuable knowledge may be said to consist. Hence the importance of statistics, which supply the raw material, to be afterwards fabricated by the delicate hand of science into those fine but not flimsy speculations, which give importance to the most trifling circumstances, by shewing how they bear on great principles; and hence, by the unexpected analogies which they often disclose in the practice and policy of nations, a new light is reflected on the history of mankind.

It is not, however, from a mere barren collection of facts that instruction can be derived. The statist must be so far trained in the school of philosophy, as to be able to cull out what is instructive, and cast aside what is useless. He must not be a mere collector of unconsidered trifles. There are many uninteresting facts from which no conclusion can ever spring. A collector of information is not in this view merely a pioneer to the philosopher. He must be qualified for his task by previous knowledge. He must know what questions to ask, into what useful channel to guide his researches, otherwise he would waste his labour in the vain accumulation of useless details, which would rather be an incumbrance than an aid to scientific inquiry. A brief enumeration of the chief facts connected with the different subjects of political science may serve more clearly to explain our views. Every subject to which the statist directs his attention has its appropriate facts. Thus, the ratio in which population and subsistence respectively increase, and the condition of the people in different countries, can only be illustrated by an accurate census at different periods, by the proportion of marriages to the whole population, and of births to deaths; and the same facts will indicate the healthiness or unhealthiness of the different countries; the population slowly increasing where the deaths are few, and being renewed more rapidly by frequent marriages, where there is a greater mortality.

In giving an account of the commerce of a country, the facts sought after must chiefly be, the amount of its exports and imports; the general rate of wages; a copious list of prices; the state of the currency; of what it consists, whether of gold, silver, or of paper; and if of the latter, the number of banks, the amount of the circulation, the price of gold and silver, and such other facts as may throw light on the difficult subject of those mercantile convulsions, and of other causes, with which we are now unfortunately so familiar.

In an investigation of the revenue, its amount for a series of years must be ascertained; the different taxes, with the annual products of each; the time when they were imposed; their increasing or decreasing amount; by which a judgment may be formed of their productiveness, and of the condition of the country in which they are imposed.

The state of a community in respect to crime is a subject of deep importance; and the facts naturally sought after must be the number of criminals tried, the nature of their offences, the number condemned, the punishment inflicted, the state of the prisons; whether there are any penitentiaries, and by what rules conducted; by which the inquirer, be he statesman or philosopher, will be able to appreciate the influence of the penal code on the morals of the country, and whether it tends to one of its great ends, namely, the reformation of the criminal, as well as his punishment.

The produce of the soil, in all its various departments, with the laws by which it is distributed among the other classes of the community, opens a wide field of inquiry; and the facts which throw light on these subjects are of great value, and must chiefly be, the amount of the produce in different years, whether scarce or abundant; the prices in these different years, and the amount of importation or exportation, with the fluctuations of price that may occur in different periods of the same season.

The mineral riches of a country, its fisheries, either on the shores or in the rivers, its climate, the diversity of its surface, and the variety of its vegetable produce on the mountains and in the plains, are all the legitimate subjects of statistics, which, it will be thus seen, has a wide range, and is connected with various sciences; 1st, with mineralogy, chemistry, and mechanics, because of the importance of those sciences in the extraction of metals from the earth, in refining the ore from the dross by the most economical modes, and in protecting those subterranean regions from the inun-

Statistics. dations of water, from the corruption of the air, or from the falling of the superincumbent masses under which the work is carried on; 2d, with meteorology, from the influence of the atmosphere on the soil; from the variation of the climate, according to the altitude, and the varieties of the vegetable tribes which are found at different heights, all which are important facts in the statistics of every country; and, 3d, with zoology, from the necessity of ascertaining the different breeds of the domestic animals, and their qualities, and how far they can be made subservient to the purposes of man. How curious it is to contemplate the varieties of these animals in different climates and countries: how in Asia the elephant, whose gigantic strength could crush its masters in the dust, is yet, by the ingenuity of man, reduced to one of the humblest of his drudges; the camel in like manner to be a pattern of patient service; and the swift dromedary, and the wild ass, with its indomitable spirit, broken to the yoke, though in the eastern countries still retaining its native fire; while in Europe man depends upon an entirely different class of animals, whose properties are of the highest importance in reference to the various duties to which they are appointed, and form, therefore, the proper subject of statistical inquiries, to which zoology contributes its aid.

The moral and religious condition of the people is a subject of still greater importance, which cannot be understood without knowing the nature and extent of the religious establishments and seminaries of education; the funds that are appropriated for these purposes, and their efficiency for their proposed ends; from what source they are derived; whether they are large or small; the number of churches and schools, as compared with the population; the nature of the different seminaries; what are the sciences taught; the pay of the teachers, civil as well as religious; the different sects; the number of each; the proportion of those teachers who are paid by the state to those who depend on the voluntary contributions of their flocks. All these facts are necessary to be known in order to decide on the great questions which will ever agitate the world on the subject of religion, namely, whether any particular form ought to be encouraged by the state; whether it is not the better policy to leave religion to its own native and divine strength; to give protection to all, but encouragement to none; a fair field and no favour; whether religion is more effectually promoted by a largely endowed ministry, or by one more humble and industrious, depending for their subsistence on the good will of their people; whether large pay may not be a source of corruption and a bribe to indolence; or whether such a class of luxurious priests may not be necessary to propagate religion among the rich. It is by inquiries into facts such as we have enumerated that these important questions can be best elucidated; and it is to these objects, therefore, of which we have given an imperfect enumeration, that the statistical inquirer ought to direct his attention, with a view of clearing away all obstructions from the paths of science.

The study of statistics has only been of late years systematically prosecuted. It makes no part of the early history of nations. The glare of battles, and of political commotions which fix the destiny of nations, alone attracts the notice of the historian; and for these, the more precious details of domestic history are thrown into the shade, and finally lost. It is only, therefore, that portion of human affairs, which, though more striking, is the least valuable, that history embalms, while it casts aside as useless those important facts which illustrate the progress of society, in arts, in literature, and in science; in wealth also, in population, and in commerce, by new and more ingenious modes of industry, which shew the changes of manners that follow increased wealth, the state of the public revenue, with various other topics equally interesting to the statesman as well as the

philosopher. The ancient history of Greece and Rome is eminently deficient in those details. The writers of those times appear to be extremely loose in their facts; and they very seldom refer to the authority of any original document. In the ancient republics of Greece and Rome, every thing was subservient to war; and the accounts that were from time to time taken of the male population, were with a view to ascertain the military strength of the state. But little reliance can even be placed on these accounts. The ancient historians were rather intent on general description, often vigorous and eloquent, than in any accurate appeal to facts. There was no accurate census of the Roman empire after it had attained to the height of its power; and the Roman historian, admitting that the number of subjects cannot now be fixed "with such a degree of accuracy as the importance of the object would deserve," is reduced to little better than conjecture, when he estimates the number of persons under the imperial sway at 120 millions; "a degree of populousness," he adds, "which possibly exceeds that of modern Europe;" the vague manner of his expression truly intimating the imperfect data with which he was furnished. In other departments the statistics of Rome are still more deficient in facts. The relative proportions of births, deaths, and marriages, are never so much as pointed at in any historical work; and the accounts that remain of the state of commerce and manufactures are meagre in the extreme. A list is no doubt given of articles of luxury imported into Rome, and of the trade to India and Arabia; in which Pliny complains of the unfavourable exchange, a modern complaint, also, in this country, and of the drain of gold which it occasioned, there being no other equivalent with which the rare luxuries of those countries could be purchased. (See the article ARABIA.) But we have no account of the state of wages, of the value of the exports or imports, nor any very accurate account of the currency, or of the public revenue. The modern historians of Rome, gleanings a few scattered facts which shed an incidental light, from the works of the classical writers, are reduced, by the help of their own conjectures, to form them into a specious, but often doubtful hypothesis. What a meagre account, accordingly, does the illustrious Gibbon, not less noted for eloquence and fancy, than for accurate research, give of the revenues of Rome. He begins with lamenting the want of any authentic document. "History," he observes, "has never perhaps suffered a greater or more irreparable injury than in the loss of the curious register bequeathed by Augustus to the senate, in which that experienced prince so accurately balanced the revenues and expenses of the Roman empire." And when groping his way, by the imperfect light which history supplies, he estimates that 20,000 pounds weight of gold were annually received from the provinces of Austria, Gallicia, and Lusitania, he adds, "we want both leisure and materials to pursue this curious inquiry through the many potent states that were annihilated in the Roman empire." After stating the incidental circumstance of Augustus having once received a petition from the inhabitants of Gyarus, a solitary and desolate isle, for a remission of their annual duties, which only amounted in value to L.5 sterling, and naturally inferring, if such severe attention was directed to the abodes of sterility, that much larger contributions would be levied in the seats of population and of wealth, he adds, "from the faint glimmerings of such doubtful and scattered lights, we should be inclined to believe, that with every fair allowance of times and circumstances, the general income of the Roman provinces could seldom amount to less than L.15,000,000 or L.20,000,000 of our money." Such is all the information which the most diligent research could collect from any extant record concerning the revenues of Rome. What a contrast does this present to the enlightened science of modern times, and to the more accurate documents prepared by authority in the great states of Europe,

Statistics.

Statistics. and in America, in which their respective revenues and expenditure are detailed with arithmetical accuracy; not only the general result, but also the amount of the duty on such separate articles for a series of years, from which we are enabled to draw important conclusions as to the nature and policy of different taxes, as to the general effect of taxation, and the condition of the country, whether, as indicated by the state of its revenue, it is advancing or going back.

Under the imperial government of Rome the land was accurately measured by surveyors, who reported its produce, whether arable or pasture, vineyards or woods, what was the number of slaves or cattle; and an average estimate was made of its produce for five years, on which a fixed proportion was exacted by the state. But nothing remains of the records to point out the state of property in this great empire, the chief seat of wealth and civilization in the ancient world; and it is lamentable to reflect, that most of those inquiries by government were instituted, not with any view of promoting science, or of benefiting the people, but rather of plundering them: their rulers inquired into their means that they might know how heavily they might be burdened. This was probably the origin of that exact survey of the lands of England which took place by order of William the Conqueror, which was finished in six years, and was entered into the register called *Domesday-Book*; not only a relic of antiquity, but a statistical document equally valuable and curious, more especially considering the rude age in which it was produced. Neither in that early age, however, nor in much later times, are there any materials for domestic history; and accordingly the English historian, in describing the progress of manners, is reduced, like the historian of Rome, to draw his imperfect conclusions from the few facts which are scattered through the pages of the early writers.

When the progress of political science became more rapid, the facts on which that science was founded, were investigated with redoubled assiduity. Towards the close of the seventeenth century, several treatises were published on the subjects of commerce, manufactures, circulation, and finance, by Reynolds, Child, and Petty. But they were deficient in comprehensive views, and attracted comparatively little attention. The more recent works of Price, Arthur Young, and Playfair, on population, commerce, and agriculture, though evincing laborious research, are liable to the same objection. Dr. Smith was the first writer who laid open the philosophy of commerce, and the publication of his work was an era in the science. It attracted universal attention; and carried conviction wherever it was studied, by the force and the extreme simplicity of its reasonings. The far-reaching views of the author into all the complicated relations of society, are not more striking than the perfect plainness with which he lays open its hidden structure. There is a peculiar force and propriety in his style, which, repudiating the use of ornament, possesses a weight and brevity which is quite remarkable. It is the pure ore of expression, refined from all those inconvenient accessaries of speech which encumber the modern languages. His argument often appears to consist of a series of insulated propositions, yet they are linked together into so fine a logical chain, that the mind is carried on step by step to the grand and striking conclusion. Since the publication of Dr. Smith's work, statistical knowledge has been more and more sought after, and many valuable

Statistics. works have been published on the subject. Among these may be mentioned the *Statistical Account of Scotland*, to which the clergymen throughout the country contributed each the account of his own parish. The design of the work, which was begun about the year 1791, and was suggested by Sir John Sinclair, to whom the accounts were sent, and who superintended the publication, is extremely judicious, and the execution is in general useful and accurate. In these volumes was accumulated, in respect to Scotland, a greater portion of correct information than had ever before appeared. The work is useful as a memorial of the condition of the country at that period, and as an illustration of domestic history. The great improvements which have taken place in the country, have now rendered obsolete most of the information which it contains; but a new work on the same plan is now in the course of publication at Edinburgh; and so far as it has proceeded, it appears to be executed with judgment and care, and to contain an ample store of statistical information.

But those publications, valuable as they are, fall short of the important documents which are now annually laid before the respective legislatures of different countries. Great Britain, France, and the United States, possess, in these public accounts and papers, a valuable mass of political information, and the most authentic details on all the important subjects of commerce, agriculture, finance, the moral instruction of the people, and on every other branch of domestic history. And the great advantage is, that we can appeal to these accounts with the most perfect confidence. They are the solid materials of philosophy, the original sources from which are drawn those unerring conclusions concerning the laws and structure of society which nothing can reverse; which equally survive the tempests of revolution, and the change of manners. On important subjects, the British Parliament often appoints a select committee of members to make inquiry, and to prepare a report. They have authority to summon witnesses, and to collect evidence from every quarter. The diligence and ability with which those committees have executed this task, is attested by the long and elaborate reports which are among the parliamentary papers on the revenue, on trade, on agriculture, on banks and paper currency, and on almost all the different manufactures which are carried on in the country; such as glass, soap, starch, paper, malt, the distillation of spirits, the brewing of beer, and others of less moment. It is of great importance that the accuracy of these, and the accounts which they contain, should be undisputed, or otherwise their effect would rather be to mislead than to inform.¹ The information that is now called for by Parliament, is much more extensive than in former times, and relates to matters that were formerly thought to be of the most private nature. Prior to the suspension of cash payments by the Bank of England in 1797, nothing was known of its circulation or of its operations; and Dr. Smith, however justly he expounds the nature of money and of paper currency, had no knowledge whatever of the amount that circulated in the country. No accounts of this nature were published at that time. These were official secrets, which were to be rigidly kept from the eyes of the profane. The catastrophe which befel the bank in 1797, broke the spell of secrecy; the various committees which have been appointed to inquire into the affairs of the bank, namely, the Lords' committee of secrecy in 1797, in 1810, and in 1819, and the committee of

¹ We think it necessary to give this caution, as we entertain doubts of the accuracy of an important table inserted in the Seventh Report of the Commission of Excise Inquiry, in which is given the amount and progressive increase of the duties on spirits in Scotland; with the quantity, as far as can be ascertained, annually brought to account. It is stated in the report, that the mode of charging the duty per gallon of still-content was discontinued in Scotland in 1802; and, in the table, the highest amount of duty on the cubic contents of the still in the Lowland district, is stated to be L.64, 16s. 4d.; whereas the 46 Geo. III. c. 102, passed in 1806, raises the permanent duty on the cubic contents of the still to L.108, and adds the war-duty of L.54, to continue till six months after the definitive treaty of peace. It was not till the year 1814 that the duties were transferred from the cubic contents of the still to the wash and the spirit, at the rate of 1s. on the former, and 2s. 10d. on the latter. See 54 Geo. III. c. 172. The facts given in the table are at variance with the acts of Parliament which we have quoted.

Statius. the Commons in 1832, have both laid open the transactions and policy of the bank; and a quarterly account is now ordered to be published in the Gazette of its circulation, its deposits, its liabilities, and the average amount of its stock of gold. Such information gives to the political inquiries of modern times an incalculable advantage. The progress of freedom in Europe also conduces to the extension of statistical knowledge. Where popular assemblies are established, with the right of free discussion, inquiries into all the branches of the public service will naturally follow. Papers and accounts will be called for; no longer will the transactions of statesmen be shrouded in darkness; they will be dragged into light; and the people formerly reprobated by the tyrant Henry VIII. as brutes, who were no more judges of these high matters than a blind man of colours, will insist, in their boldness and presumption, to know how their money is spent. Thus will be obtained the financial accounts of the kingdom, and those of commerce, and other public matters will follow in due course. Publicity is the true corrective of corruption; and in the pure administration of free states, the ruler will rather court than shun inquiry, being conscious of nothing that will not bear the light. Accordingly, in 1832, a statistical office was established in the department of the board of trade, for the purpose of collecting, arranging, and publishing statements relating to the condition and the various interests of the British empire. The volumes to which this arrangement has given birth, are annually printed and laid before Parliament, and contain an ample store of the most satisfactory details. Several societies have since been formed for prosecuting statistical inquiries. In 1833, a statistical section was formed in the British Association for the advancement of Science during the period of its meeting at Cambridge; and, before the close of the year, the Manchester Statistical Society was established. The Statistical Society of London, which had been projected at Cambridge, was established in 1834, and has published a monthly journal, which contains much useful information. Statistical societies have been formed in other populous towns, in Liverpool, in Bristol, and in several towns in Ireland, and promise, by their industry, to add largely to the existing stock of useful knowledge. Many important publications have of late years issued from the press, on the condition and resources of the country; on its commerce, its agriculture, its currency, as well as on the state of education, which tend to promote, and greatly to aid statistical inquiries. The most important of these is Macculloch's Dictionary of Commerce, a work which combines extensive research, and the most copious details, with the spirit of philosophy. Other statistical works are, the Statistical Account of the British Empire, by the same author; Statistical Accounts of part of Ireland, by the Officers of the Irish Ordnance Survey; Milburn's Oriental Commerce; Macgregor's Statistics of Nations; Porter's Progress of the Nation; Martin's Colonial Magazine, and his British Colonial Library, an elaborate account of the colonies. An instructive and useful work has lately been published by Mr. A. Trotter on the Commerce and Banking System of the United States, which is a compendium of important statistical information. With all these aids, political science will undoubtedly advance, and may be expected in time to attain to more certain results in all those important inquiries which relate to the actual condition and moral improvement of mankind. (Y.)

STATIUS, PUBLIUS PAPINIUS, a celebrated Latin poet, who was born at Naples, A.D. 61. His father was of a patrician family, but being poor, he maintained himself by teaching rhetoric, first at Naples, and afterwards at Rome. The emperor Domitian is said to have been one of his pupils. He was a master of the Greek as well as the Latin tongue, and was a poet as well as a rhetorician. If we could rely on the statements of his son, he was little

inferior to Homer in poetical genius; but as his contemporaries have nowhere noticed him, it may fairly be presumed, that his affection for his father blinded the son's judgment.

Statius received his education at Rome, and married at an early age (A.D. 81) a widow named Claudia, whom he frequently mentions in his verses. He was distinguished by his powers as an improvisatore, which seem to have been very considerable, and he often appeared before the public in the poetical contests of the age. In these he was not unfrequently victorious; yet though crowds flocked to hear the recitation of his *Thebais*, Juvenal, Sat. vii. 87, remarks, that he would have perished from hunger, if he had not been able to sell to the principal actor of the day his tragedy of *Agave*, which is now lost. His high reputation however excited against him many enemies, and among others Martial, who, it is observed, never took any notice of Statius. The principal poem of Statius is entitled *Thebais*; it is an epic poem in twelve cantos, and a work of considerable merit. It relates to the Theban war under the sons of *Cedipus*, and is in reality, like that of *Silius Italicus*, an historical poem, the materials for which have been drawn principally from Greek sources, more particularly from the *Thebais* of *Antimachus*. He has taken for his model *Virgil's Æneid*, but has not been very successful in his imitation. Another of his poems is entitled *Achilleis*, being intended to exhibit a detailed account of the life and deeds of *Achilles*, from the moment of his birth; but the author did not live to complete his plan, and only two books remain, the last of which is imperfect. This portion contains only a small part of the life of *Achilles*. We have besides a collection of thirty-two poems, divided into five books, and bearing the title of *Silvæ*. They are mostly in hexameter, but some few in *Alcaic*, *Sapphic*, and *Phalæucian* verse. Having fallen into a feeble state of health, he retired to *Naples* in the hope of deriving some benefit from his native air. Here he laboured at his *Achilleis*; but death arrested his progress before he had completed the thirty-sixth year of his age.

The poems of Statius exhibit nearly the same faults as are to be found in the works of *Silius Italicus*, and *Valerius Flaccus*. He possesses the rhetorical spirit of his age, which, disregarding the beauties of simplicity, aimed at effect by ingenious turns of expression, and a display of great learning. His language is sometimes bombastic. His works were at one period, not of the most refined taste, held in as great estimation as those of *Virgil*. The first collective edition of his poems appeared at Venice in 1483, folio. They had been separately printed at an earlier period. The subsequent editions are sufficiently numerous. Among the more elaborate of the early editions, we must mention that of *Lindenbrog*, Paris. 1600, 4to. It includes the scholia of *Lactantius*, or *Lactatius*, on the *Thebais* and *Achilleis*. Nor must we omit the accurate edition of *Gronovius*, Amst. 1653, 12mo. The same able critic had previously published "In P. Papinii Statii *Silvarum* libros v. Diatribe." Hagæ Com. 1637, 8vo. An edition of Statius was not long afterwards published with the very elaborate and learned commentary of *Barthius*, Cygnæ, 1664, 2 tom. 4to. The commentator was then dead, and the edition was superintended by *Daumius*. Considerable additions were here made to the ancient scholia formerly printed. Another critic to whom this poet has many obligations, is *Markland*, who published, with notes and emendations, a separate edition of the "*Silvarum libri quinque*." Lond. 1728, 4to. Among the attempts at English translation, we may mention *Lewis's* version of "*The Thebaid of Statius*," Oxford, 1767, 2 vols. 8vo.

STATUARY, a branch of sculpture, employed in the making of statues. See **SCULPTURE**.

STATUE, is defined to be a piece of sculpture in full relief, representing a human figure. See **SCULPTURE**.

Statuary,
Statue.

S T E A M.

Steam.

THE articles STEAM and STEAM-ENGINE in the third edition of the present work were originally written by DR ROBISON, and were long the standards of reference upon these subjects. The rapid progress of science and of the mechanical arts during the present century, has now rendered it necessary to substitute for these articles those maturer results of recent research, to the attainment of which the original papers were themselves the means of very materially conducing. The value of these original researches was further enhanced by passing through the hands of the man of all others the most capable of appreciating their value, and the best qualified to increase it by his contributions. It was the early friend and companion of Professor Robison, Mr WATT himself, who, towards the close of his life, and notwithstanding the laborious nature of the undertaking, agreed to revise those articles for republication, so as to present them to the public with somewhat of that greater completeness which it is to be presumed their author would himself have conferred upon them, had he lived to see the investigations which he had begun, carried forward and completed. Mr Watt was, however, prevented by the weakness of increasing years from doing more than adding notes to these articles, and they were accordingly printed in that form; but they contain a most interesting chapter of the history of inventive genius, for they give us, in Watt's own words, the history of the progress and consummation of his own noble inventions, and display the efforts of genius working its way through the obscurities of imperfect knowledge to the discovery of pure truth and the achievement of the most exquisite combinations.

While, therefore, it was impossible to retain the articles themselves, it was highly desirable that all that had rendered them valuable should be retained, and more especially such portions as serve to record the state of the mechanics and physics of steam at that time, and the progress of the invention; and these, together with the notes of Mr Watt, it has been thought better to give in the precise words of the original, than to transpose them into language which could neither be more clear nor more appropriate than that with which their authors had invested them. Such portions of the articles on steam and the steam-engine, as have been in this manner retained, are distinguished by an appropriate mark. Paragraphs from the pen of Dr Robison have a star * placed at their commencement; those of Mr Watt, in like manner, have a cross †. To all that was interesting and valuable in the original articles, an attempt has been made to superadd whatever subsequent labour and research may have brought to light. These remarks apply to the articles STEAM and STEAM-ENGINE. STEAM NAVIGATION is entirely new.

SECTION I.—CONSIDERATIONS OF A GENERAL NATURE
REGARDING THE PROPERTIES, PHENOMENA AND APPLI-
CATIONS OF STEAM.

Origin of
Steam.

1. * STEAM is the name given in our language to the visible, moist vapour which arises from all bodies which contain juices easily expelled from them by heats not sufficient for their combustion. Thus we say, the steam of boiling water, of malt, of a tan-bed. It is distinguished from smoke by its not having been produced by combustion, by not containing any soot, and by its being conden-

sible by cold into water, oil, inflammable spirits, or liquids composed of these. Steam.

2. * We see it rise in great abundance from bodies when they are heated, forming a white cloud, which diffuses itself and disappears at no very great distance from the body from which it was produced. In this case the surrounding air is found loaded with the water or moisture which seems to have produced it, and the steam seems to be completely soluble in air, composing, while thus united, a transparent elastic fluid.

3. * But, in order to its appearance in the form of an *opaque white* cloud, the mixture with or dissemination in air seems necessary. If a tea-kettle boils violently, so that the steam is formed at the spout in great abundance, it may be observed, that the visible cloud is not formed at the very mouth of the spout, but at a small distance before it, and that the vapour is perfectly invisible at its first emission. This is rendered still more evident by fitting to the spout of the tea-kettle a glass pipe of any length, and of as large a diameter as we please. The steam is produced as copiously as without this pipe, but the vapour is transparent and colourless throughout the whole of the pipe. Nay, if this pipe communicate with a glass vessel terminating in another pipe, and if the vessel be kept sufficiently hot, the steam will be as abundantly produced at the mouth of this second pipe as before, and the vessel will remain quite transparent. The visibility, therefore, of the matter which constitutes the steam is an accidental circumstance, and appears to require its dissemination in the air; and we know that one perfectly transparent body, when minutely divided and diffused among the parts of another transparent body, but not dissolved in it, makes a mass which is visible. Thus oil beaten up with water makes a *white opaque* mass. Colour of Steam.

4. If the column of steam which ascends from a boiler that is suddenly opened, be observed in a clear dry day, when the sun is shining, the column of vapour, gradually widening as it rises, will be observed to be of a very brilliant silvery white, and will cast a strong dark shadow upon the objects which it intercepts from the direct rays of the sun: but, if the observer be placed in this shadow, the sun will appear to him to be of a strong tawny, or fiery red colour, or, if the column be very dense, the sun will be invisible. These appearances closely resemble some phenomena of the clouds, which we know are composed of watery vapour, and which sometimes appear of a fleecy white, again of a fiery red or a burnished gold colour, or again of a dappled grey, down through every degree of darkness, until the vapour become so dense and opaque as altogether to obscure the light of the sun by a thick black cloud. These appearances have been satisfactorily accounted for. Steam, in its attenuated state, is a transparent, invisible, colourless gas. When disseminated through the air, in excessive quantities, small globules are formed, of a film of water, enclosing light vapour. These globules, floating thickly in the air, form an aggregation of minute films of fluid, capable of reflecting and transmitting light. When we are so placed that the light may be reflected to us, and when the cloud is so thick as to reflect it completely, we have the same brilliant white which results from the comminution of glass, rosin, ice, and other transparent media; and, at the same time, an observer, placed on the opposite side of the cloud, sees it as a dense black opaque mass, because the light being totally

Steam. reflected, none of it can be transmitted to him. The richer colours transmitted by thinner strata of vapour are thus noticed by M Leopold Nobili of Reggio. "The tints exhibited by the clouds in every variety of aspect are almost all comprised in Sir Isaac Newton's first ring (the white, yellow, orange, red; or the blood, tawny, copper, ochre, and fire red, and violaceous red, or No. 1-12 of Mr Nobili's scale). Tints of this kind do not arise from refraction and diffraction, they are produced only *by means of thin plates*. Now the measurements of Sir Isaac Newton have shown what are the dimensions of the layers of air, of water, and of glass, which produce the colours of the several rings; and, as we know that the vesicular vapours are formed of water, and that they do not reflect or transmit any other tint, we may conclude that their external film is in no case thicker than ten millionth parts of an inch. This result appears to me to be so decidedly certain as to be entitled to a place in science." It was to the effect of thin plates on light that Newton referred the colours of all bodies; and the accounting for the rich golden hues of the clouds, and the fiery red colour of light passing through dispersed steam, by the effect of the thin plates of water enclosing the vapoury spheroids of pure steam, must be regarded as one of the most satisfactory applications of his theory. (See article OPTICS.)

Apparent
annihila-
tion of
Steam.

5. A very singular phenomenon takes place, if the flame of a candle or lamp be held below a jet of steam, as it issues from the mouth of a small pipe; the steam instantly ceases to be visible. In this case, one of two changes may be conceived to take place, either or both of which account for the permanent invisibility of the vapour: the intense heat of the flame may disperse the particles to such a distance, that there does not remain in a given space a sufficient number to form a vesicle of vapour, and it therefore remains diffused in combination with the air, which always holds a large quantity of invisible vapour, especially at high temperatures; or the vapour may be decomposed by the flame into the permanent and invisible gases, of which it consists, which may again become combined, to a certain extent, with the burning substance, and support the flame.

The matter
of Steam.

6. * When steam is produced, the water gradually wastes in the tea-kettle, and will soon be totally expended if we continue it on the fire. It is reasonable, therefore, to suppose that this steam is nothing but water, changed by heat into an aerial or elastic form. If so, we should expect that the privation of this heat would leave it in the form of water again. Accordingly, this is fully verified by experiment; for, if the pipe fitted to the tea-kettle be surrounded with ice, or any cold substance, no steam will issue, but water will continually trickle from it in drops: and if the process be conducted with the proper precautions, the water which we thus obtain from the pipe will be found equal in quantity to that which disappears from the tea-kettle. Steam is therefore the matter of water, converted by heat into an elastic vapour.

Conditions
of the
matter of
Steam.

7. Steam, water, and ice, are three conditions of the same substance, which it assumes under different circumstances of heat and of external pressure. In each condition it obeys different laws; as a solid, ice obeys the laws of the mechanics of solid bodies: in Russia it is quarried like rock, and is used for building houses and paving ways; it is cast into moulds for domestic purposes, like iron or lead; it is painted like alabaster, and chiselled like marble: as a liquid, water is the exemplar of the hydrostatical laws of all fluids: as a vapour, it obeys the laws of aerostatics; and we now know that steam is, in all respects, similar in its constitution and phenomena to all other elastic fluids or gases. If we apply heat to a bar of extremely cold ice, it expands like other solids with heat, gradually elongating with its increased temperature, its particles receding

from one another by the repulsive action induced between the particles by the entrance of caloric between them, the cohesion of the particles becoming less and less, until at last, if the heat be continually thrown in, the cohesion of the particles is altogether overcome, they lose their aggregation, they become separable without effort, and, falling to pieces, the bar of ice loses its form and subsides into water. When thus melted, the water being placed in a vessel, and having heat applied to it, will, like other fluids, continue to expand from its point of greatest density, and will increase in bulk nearly one-twentieth by about 172°, but at last the entrance of so large a quantity of heat will produce a repulsive force between the particles so strong as to cause them suddenly to spring apart from one another, so as to recede to a distance twelve times as far asunder as in the state of water, and they have now assumed the aerial condition of gas or vapour, and constituting steam, occupy 1728 times their original space. The ice passing into the condition of water, is said to be *liquefied*, and the heat necessary to convert ice into water is called the *caloric of liquidity of ice*, or the *caloric of condition of water*; when water is converted into steam, the quantity of caloric necessary for this purpose is called the *caloric of vaporization of water*, or the *caloric of elasticity of steam*, and the water is then said to *boil* or *evaporate*. This process may be reversed. If the steam have been collected in a close receptacle, it may be squeezed by external compression into its original bulk, or by cooling the outside so as to withdraw the caloric of elasticity from between the particles, they may be allowed to come together by the attraction of cohesion, and resuming their original proximity to each other, appear once more in their former condition of water, and in this case the *vapour* is said to be *condensed*; and if the process of abstraction of caloric, with sufficient pressure, be continued, the liquid particles approaching each other, will gradually contract the bulk of the mass, and at a certain point will take again the original character of ice, and the *liquid* is then said to be *congealed* or *frozen*. The same particles of matter do "thus in turn play many parts."

Ice melts and becomes water by increment of heat.

Water evaporates into steam by increment of heat.

Steam is condensed into water by decrement of heat.

Water congeals into ice by decrement of heat.

(8.) These phenomena are not confined to one substance: many substances, apparently the most refractory, of the Steam one
Gases.
have been melted and again congealed, while other substances which had never been observed in any other form than that of transparent air or invisible gas, have been condensed by the expedients of modern artifice into liquids heavier than water, and have even been congealed into hard and strong solids. To so great an extent has this taken place, that we are now almost warranted in deducing, from a wide induction of facts, the following generalization; that all bodies assume the solid, liquid, or gaseous condition, according to the accidents of temperature and pressure under which they happen to be placed; and that it is merely from the circumstance of their being more ordinarily found, at the present temperature of the earth and under the weight of our present atmosphere, in one of these states rather than another, that some substances have been characterised and distinguished, and classed as permanent solids, liquids, or airs. We now speak of ice only as frozen water; but had we lived under a temperature such as that which the inhabitants of the planet Jupiter, at their distance from the sun, may be conceived to endure, we should have spoken of swallowing *melted ice* as we now speak of molten lead, and a separate name for melted ice would have remained unknown; or, if we conceive, in like manner, our air to be withdrawn, and the

Steam. temperature of the earth raised above 212° , we should then have moved under an atmosphere of steam of the same pressure as at present, transparent and colourless, and might only have heard of water as a curious substance obtained from the compression of the air. The phenomena of steam are much simplified and more perfectly explained when we take this enlarged view of its analogy with other kinds of matter.

Phenomena of Ebullition.

9. We are most familiar with steam when in the act of rising violently from heated water in the process of *ebullition*. The history of steam at this crisis is highly instructive, and its phenomena may be studied with advantage by examining it in a glass vessel placed over a strong lamp. When heat is first applied, a rapid circulation of the fluid ensues. The water on the bottom, being first heated and expanded, becoming lighter than the rest, rises to the top, and is replaced by the current of colder water descending to receive in its turn a further accession of heat. By and by, small globules of steam, formed on the bottom and surrounded by a film of water, are observed adhering to the glass; as the heat increases they enlarge, in a short time several of them unite, form a bubble larger than the others, and, detaching themselves from the glass, rise upwards in the fluid. But they never reach the surface; they encounter currents of water still comparatively cold, and descending to receive from the bottom their supply of heat; and encountering them, the bubbles are robbed of their heat, shrivel up into their original bulk, and are lost among the other particles of water. In a short time the mass of the water becomes more uniformly heated, the bubbles, becoming larger and more frequent, are condensed with a loud crackling noise, and at last, when the heat of the whole mass reaches 212° , the bubbles from the bottom rise without condensation through the water, swell and unite with others as they rise, and burst out upon the air in a copious volume of steam, of the same heat as the water from which they are formed, and pushing aside the air, make room for themselves. In this process, by continuing the application of heat, the whole of the water may be "boiled away" or converted into steam.

Sounds of Simmering and Ebullition.

10. The singular sounds produced from a vessel of water exposed to heat, previously to boiling, have attracted attention; the water is then vulgarly said to be simmering or singing; and, when this takes place, it is because the vessel is boiling at one place and comparatively cold at another. This noise is most distinctly heard when the fire or flame applied is small, and its heat intense, when the vessel is large and the water deep; for in that case the entrance of the caloric will take place more rapidly than the circulation can convey it to the remote particles of fluid, and so bubbles of steam will form rapidly at one place and be rapidly condensed at another; the degree of velocity with which such bubbles succeed will determine the pitch of the singing tone. We have observed this phenomenon in greatest perfection when we have attached a slender pipe to a close boiler producing steam, and carried its open mouth, of the diameter of $\frac{1}{8}$ or $\frac{5}{16}$ of an inch, down below the surface of cold water in a glass jar. When the mouth of the steam-pipe is held just below the surface of the water, the steam issues with great rapidity in small bubbles, producing an acute tone; and, on the other hand, when the pipe is held at a considerable depth, the concussions become more violent and louder, their intervals of succession greater, the tone is lowered, and finally, the shocks become detached, and so violent as to shake the glass and surrounding objects with much force. On this subject Professor Robison observes, *that a violent and remarkable phenomenon appears, if we suddenly plunge a lump of red-hot iron into a vessel of cold water, taking care that no red part be near the surface. If the hand be now applied to the

side of the vessel, a most violent tremor is felt, and sometimes strong thumps; these arise from the collapsing of very large bubbles. If the upper part of the iron be too hot, it warms the surrounding water so much, that the bubbles from below come up through it uncondensed, and produce ebullition without concussion. The great resemblance of this tremor to the sensation which we experience during the shock of an earthquake, has led many to suppose that the latter is produced in the same way; and their hypothesis, notwithstanding the objections which we have elsewhere stated to it, is by no means unfeasible. Any obstruction on the bottom of a boiler, on the inside, as a piece of metal or stone introduced among the water, may produce a succession of smart concussions by the sudden condensation of gas collected under it.

11. The permanence of the boiling point is one of the most remarkable of the phenomena of ebullition. When water has once been brought to boil in an open vessel, it is not possible to make the water sensibly hotter, however strongly the fire may be urged or its intensity increased. This circumstance is very striking, because we know that heat continues to be thrown in exactly as fast as before the boiling point, and that in that case the heat rose rapidly, whereas now it has altogether ceased to increase. If a thermometer of mercury, air, oil, or metal be placed among the water, the temperature will constantly increase, and expand the matter of the thermometer, until the water boils, and then, whether it boil slowly or rapidly, with a strong fire or a gentle one, the thermometer will continue to stand at the same point. This point is so well defined, as to furnish our standard for the comparison of temperatures, and is the same on all thermometers, being called *the boiling point*, although it is differently numbered on each, being called 212° on our common thermometer or Fahrenheit's, 80° on Reaumur's, and 100° on the centigrade thermometer.

It is also to be remarked, that the temperature of the steam issuing from boiling water is the same with the temperature of the water itself, and remains equally invariable; so that all the steam produced from water boiling at 212° is itself at 212° . This remark will assist us in accounting for the disposal of the heat which the fire gives out during the time of ebullition; for it is manifest that the heat is all the while carried off by the large volumes of steam, at a temperature of 212° , that are diffused through the air; and so it happens that an increase of heat in the fire, instead of increasing the heat of the water, only increases the volumes of the steam thrown off, and the quantity of heat carried away. This view of the subject is confirmed by a simple experiment. Take a strong glass flask, place water in it and a thermometer among the water, and let it be held over a lamp until the water boil, and the thermometer will be observed rising till it reach 212° , when the steam will begin to escape rapidly from the neck of the flask. Let it now be corked tightly, and the heat continually applied; and it will be observed that the thermometer does not now stand at 212° , but rises rapidly from that point up to 220° and 230° , showing that the free escape of the steam into the open air is necessary to the permanence of the boiling point. If the heat be still applied, the experiment may be rendered still more instructive, by suddenly pulling out the cork of the flask, when the vapour will instantly rush out in a large volume, and the thermometer sink down to 212° , showing that all the excess of heat has been carried off by the steam into the air.

12. We have thus seen that a large quantity of heat may be given out to the particles of a certain quantity of water, converting them into steam, and yet that the thermometer shall afford no indication of this quantity. As soon as water boils, the whole mass is heated up to 212° ; Latent Heat.

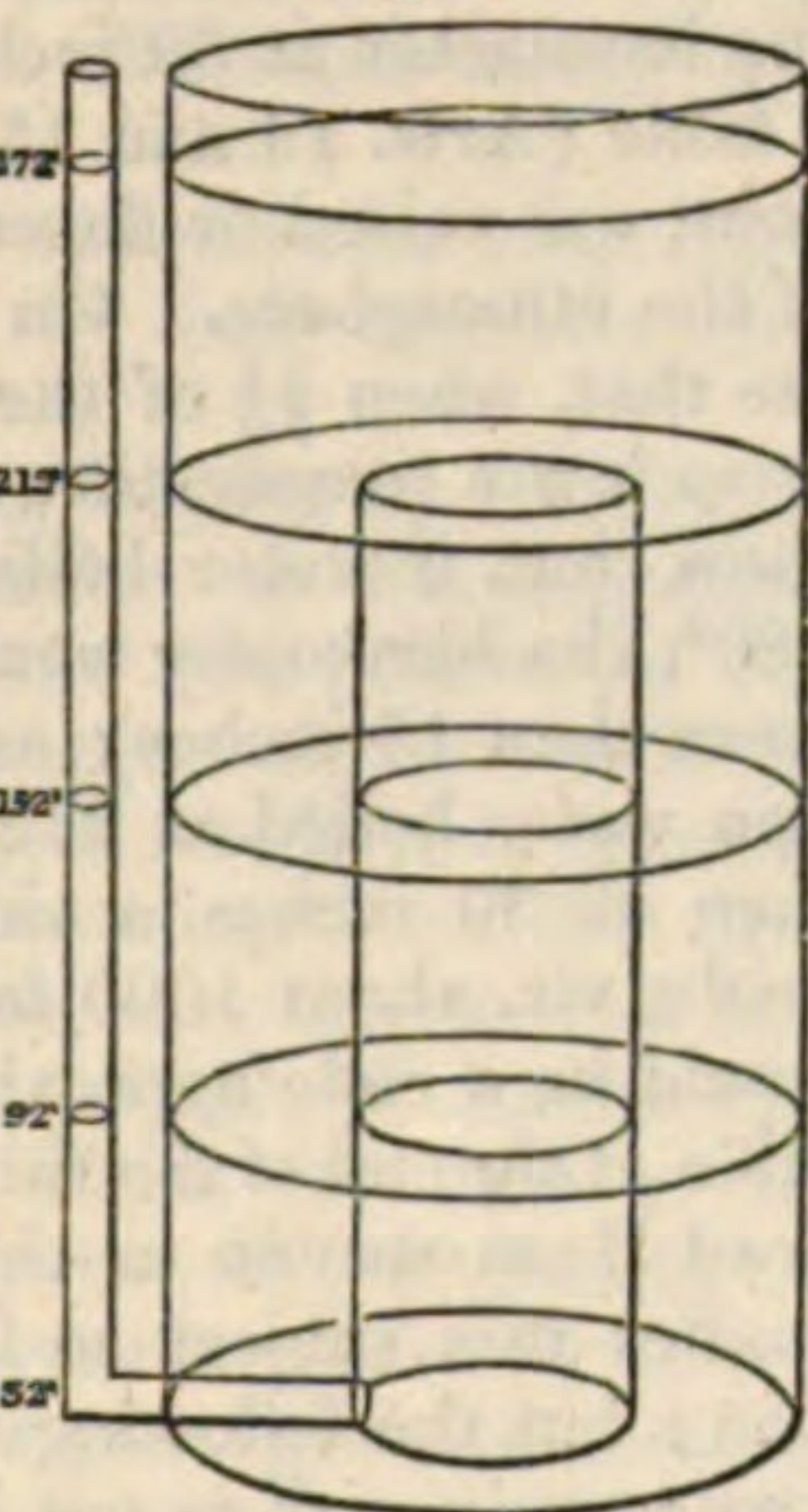
Steam.

and although the same heat that produced the ebullition be still continually applied, and although we know that this heat must be continually entering into the water, still it is not detected, or in any way exhibited by the thermometer. On this account, the heat given to water during ebullition is said to become *latent*, or lie hid from the thermometer; and, indeed, the thermometer merely indicates the intensity of heat, the calorimeter alone can measure its quantity. The quantity of heat given out to water after it has begun to boil, is more than five-fold that which is sufficient to bring it from the freezing up to the boiling point; for, if we continue the fire with the same intensity that was used in bringing it to boil, it will require more than five-fold that duration and quantity of fuel to boil all the water away, or convert it all into steam of 212° of heat. Thus the sensible heat, added from 32° , will be 180° , and that latent in the steam is more than five-fold; or, in other words, the *insensible caloric* in steam is five-fold its *sensible* heat; or the same quantity of matter in the condition of steam at 212° , and of water at 212° , will hold different quantities of caloric, in the proportion of about 6 to 1. This is called the greater *capacity of steam for caloric* than of water for that substance; and it is in part accounted for, by the greater distances of the particles of the matter of steam and water from each other in the former than the latter condition; for when the distances of the particles are increased 12 times, the spheres of caloric around each atom may be much larger, without increased elasticity of the calorific fluid. Dr Black was the discoverer of the admirable doctrine of *latent heat*.

Capacity
of Steam
for Caloric
—Dr Dal-
ton.

13. Dr Dalton has thus illustrated the doctrine of latent heat, and of the increased capacity of a liquid for holding caloric, when it passes into the condition of vapour. The liquid and its vapour may be considered as two reservoirs of caloric, capable of holding different quantities of that fluid. Let figure 1. represent to us such an arrangement; the internal cylinder of smaller capacity, the external one of enlarged capacity surrounding and extending far above it, and a small open tube of glass, communicating freely at the bottom with the inside of the cylinders. Let us now conceive water to be poured into the internal cylinder, the water will manifestly flow into the slender tube till it stand on the same level in the tube as in the cylinder. If any additional quantity be now poured into the internal cylinder, the rise of water in the slender glass tube will serve as an index of the quantity of added fluid; and when it is filled to the top, the fluid will stand at the height marked 212° , and will still be a correct index of the addition of fluid. But if more water be now added to it, it will not make its appearance in the slender tube, but will simply overflow from the internal cylinder over into that of enlarged capacity, so that, while a large quantity is passing into the vessel and gradually filling it up to 212° , no additional rise takes place until the whole of the outer cylinder become filled to that point, after which any further addition will again become sensible, by a corresponding rise in the tube. This process is in precise analogy to the succession of circumstances in heating a liquid, and converting it into steam. The internal cylinder represents the liquid, the external one the vapour of greater capacity, and the slender glass tube at the side the thermometer placed in communication with

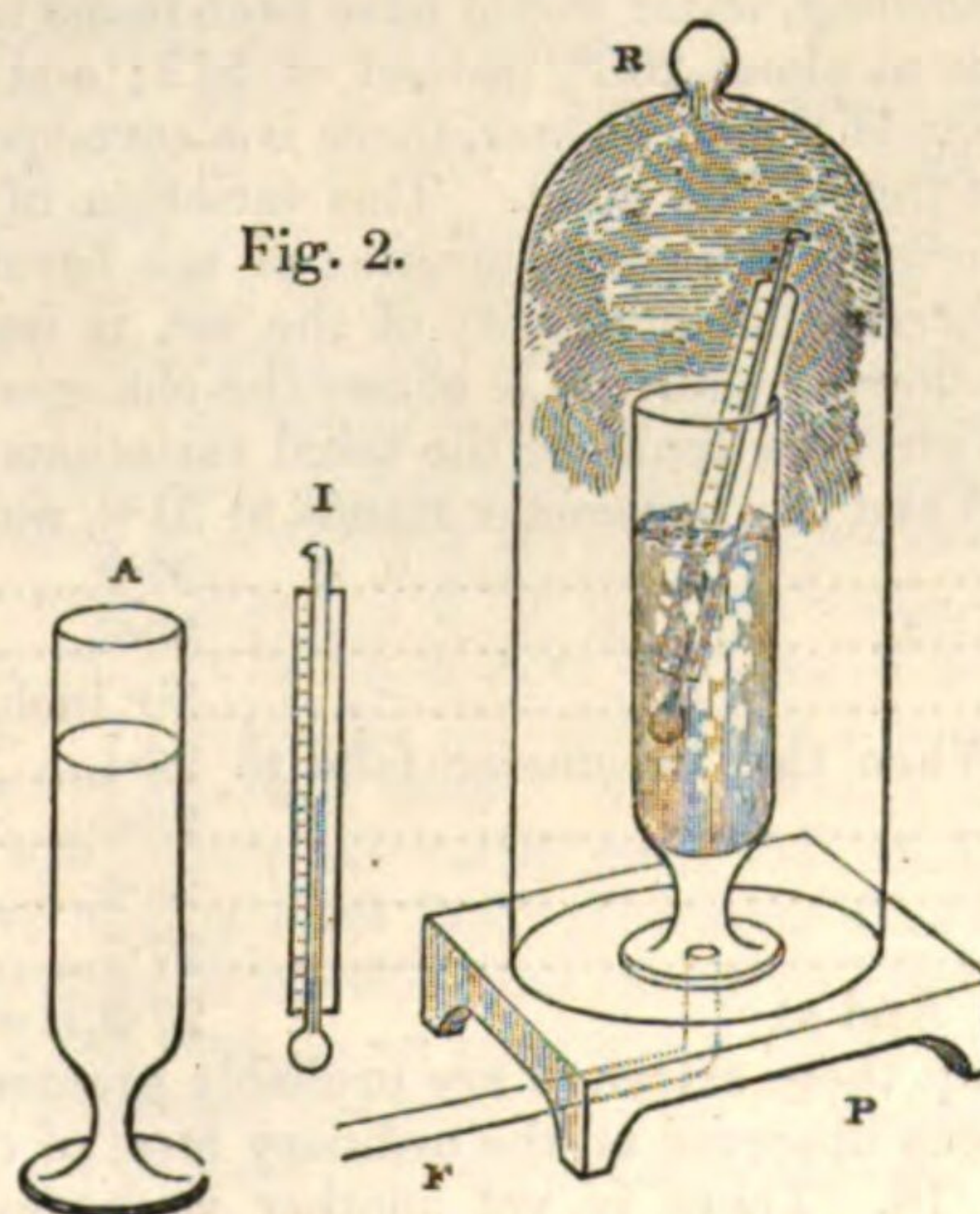
Fig. 1.



them. When heat flows into the liquid, it passes equally into the thermometer; and each increment of the one produces an equal increment in the other, until the liquid reaches the limit of its capacity, when it suddenly begins to enlarge its bulk and take the form of steam; but the quantity of heat required to fill up this enlarged capacity is so great as to require about $5\frac{1}{2}$ times as much to fill it as was contained in the whole liquid before, so that all this time the thermometer is standing still, and it is not until the whole of the steam is thus supplied with 212° of caloric, that the thermometer will begin to show any further elevation; after which, any increment of heat thrown into the steam will make its appearance on the thermometer, and proceed as formerly, by simultaneous increments.

14. It appears, therefore, that the cause why water boiling under the open air does not reach a higher temperature than 212° , is, that the steam which is raised by any additional heat, carries that additional quantity of heat along with it into the air. But here a question occurs at once to the enquirer into these phenomena, viz. Why does water require to be heated up to 212° before it will throw off its increments of heat and vapour into the air? Why does not steam rise equally strongly from water at 200° or 180° ? The categorical reply is, that the elastic force of the heat is not sufficient to enable the steam to force its way against the pressure of the air until it reaches this point. In order to understand the means by which we arrive at this conclusion, it is necessary to know that, when the pressure of air on the surface of the water is artificially diminished, the steam does actually rise, and the water bubbles and boils with great violence, at temperatures far below 212° . It is only when the surface of the water is exposed to the full *pressure of the air* in a common vessel that it is prevented from rising in vapour, at temperatures lower than the usual boiling point. If the surface of the hot water be protected from the pressure of the air, by being placed under a glass shade, and the air removed from the inside of it by an air-pump, the water may be made to boil at all temperatures below 212° . The following table contains the results of a series of experiments made, with great care, by Dr Dalton, towards the end of last century, in order to ascertain how much of the whole pressure of the air it was necessary to remove, in order to make water boil at a given temperature. In order to understand the way in which this table was formed, the reader must conceive a vessel of water first of all boiling at 212° in the open air, as the vessel A in figure 2, the thermometer I being placed in it. After allowing the water to cool to 200° , let the vessel of water and the immersed thermometer be now placed on the plate stand P of an air-pump, and covered over with a strong glass receiver R; and let a portion of the enclosed air be now withdrawn by the pump from the inside of the receiver by the pipe F; and suppose that there are in all 30 cubical inches, or other volumes, of air in the receiver at first, then the water being at 200° , when about 7

Fig. 2.



Steam. out of the 30 parts of the air have been withdrawn, leaving only about 23 parts out of 30 pressing on the water, it will be observed instantly to commence giving off steam in rapid ebullition. If next the process be repeated, only allowing the water to cool to 190°, the ebullition will not commence in this lower temperature till about 12 out of the 30 volumes of air have been withdrawn; and if, in a third experiment, the water be cooled down to 180°, the elastic force communicated by this degree of heat will not be capable of overcoming the resistance arising from the pressure of the air, until one half of the original pressure of 30 has been removed. To this process there is no limit; for as we go on lowering the temperature, we can always find a point at which the water will boil, provided the counteracting pressure be sufficiently diminished. The following is Dr Dalton's table, containing the results of his experiments, as given in his *Meteorology*, in 1793:

Heat of the Water when boiling under diminished Pressure.	Quantity of Pressure of Air remaining on the Fluid.
212°	30.0
200	22.8
190	18.6
180	15.2
170	12.2
160	9.45
150	7.48
140	5.85
130	4.42
120	3.27
110	2.52
100	1.97
90	1.47
80	1.03

Effect of Barometric changes on Ebullition — Sir John Robison.

15. In vacuo, therefore, or under a rarified atmosphere, the boiling point of water is lower than 212°. Now, the barometer informs us, that the pressure of our atmosphere is not constantly the same; it has normal and abnormal variations, it has horary, and menstrual, and annual variations. It frequently stands at 30 inches, sometimes at 31 inches; and on the morning of the 7th of January, 1839, it was observed at Edinburgh, by Sir John Robison, to be as low as 27 inches and six-tenth parts. Now, on that morning, water would have been found to boil in the open air at about 208°, instead of 212; and for every depression of the barometer, there is a corresponding depression of the boiling point. This variation of the boiling temperature with the variation of the barometer, and of the corresponding density of the air, is important: and the following short table shows the changes which take place within the limits of the usual variations of the weather:

When the barometer stands at 31.8, water boils at 215°	
.....31.2,.....	214
.....30.6,.....	213
.....30 inches,.....	212
When the barometer falls to 29.4,.....	211
.....28.8,.....	210
.....28.2,.....	209
.....27.7,.....	208
And at 27.2, it would boil at 207	

But these extremes are probably greater than have ever been observed on the ordinary level of this country.

Ebullition on mountains and in mines.

16. There is yet another variation of circumstance which affects the point of ebullition, and that is, distance from the centre of the earth and height above the level of the sea. It is well known, that, on the summit of a mountain, the pressure of the air is less than on a plain, and still less there than at the bottom of a pit or deep valley. It is now equally well known, that the cause of this is the

very limited height to which air in a dense state covers the earth, the whole atmosphere being equivalent to not more than 5 miles in depth of such air as we breathe; and it is hence obvious, that after a vertical ascent of a mile to the top of a mountain, there would be only about $\frac{1}{5}$ of the atmosphere remaining above the person on its summit. One of the highest of the Andes has been ascended to such a height, that there remained only $\frac{1}{10}$ of the whole atmosphere above the observer. Now, in this case, the barometer, instead of being sustained at 30 inches, its usual height, had fallen to 13 inches, because, according to the constitution of the barometer (See Arts. BAROMETER and PNEUMATICS), the height of the column of mercury in it is proportional to the quantity of air resting above it. Hence, a barometer being carried up a mountain by an observer, falling as he ascends, enables him to ascertain the height of his ascent. This he does with perfect precision, so as to determine accurately the height of any point of the mountain to which he has ascended, and where he has noticed the fall of the barometer from the point where it stood when at the bottom, by means of an allowance of nearly 100 feet of height for every tenth part of an inch that the barometer has fallen, as explained more fully under the heads BAROMETER and ATMOSPHERE.

The steam of water may be rendered the means of determining the height of a mountain, on the principle of diminished atmospheric pressure, so as to act as a substitute for the barometer. We have just seen that water gives off steam by ebullition, above or below the temperature 212°, according as the pressure of the atmosphere is greater or less than the standard pressure which sustains the barometer at 30 inches. And we have already given a table (Arts. 14 and 15), showing how much the boiling point was raised or depressed by diminishing the pressure of the atmosphere. On consulting Dr Dalton's table, we see that, when $\frac{1}{5}$ of the air were removed, water boiled at so low a temperature as 180°. This, therefore, would show that, if water boiled on the top of any mountain at 180°, the barometer would stand there at a height of little more than 15 inches; and if at the bottom of the mountain water boiled at 212°, showing the barometer to be then at 30 inches, a similar allowance of height being made, viz. about 1000 feet for each inch, or 15,000 feet, would be a rude approximation to the true height. The table at the end of the third section, and the rules under the head BAROMETER in this work, will enable any one who studies this subject to form rules for closer approximation; but the following table will be of use to those who may merely wish to put it in practice.

Rule for finding heights by boiling water.—Boil pure water in an open vessel at the bottom of the elevation, and observe on the thermometer the point at which it boils. Boil it again at the top of the mountain, and observe with the thermometer the height at which it now boils: the difference of temperature, multiplied by 530 feet, will give a close approximation to the height of the upper above the lower station.

This will give an approximation; but, if greater accuracy be required, it will further be necessary to correct for the difference of the temperature of the air at the two stations, in the following manner. Add the temperatures of the air at the stations, and subtract 64 from their sum, multiply the remainder by one-thousandth part of the height found; and this will be the correction to be added to the height formerly found. The result thus found will still require a slight correction for the figure of the earth and latitude of the place; but this does not amount to more in our latitude than an addition of about two feet in a thousand, which forms a second correction. This method is, however, to be regarded only as an approximation,

Steam.

To determine the heights of mountains by the boiling point of water.

Steam.

for which all the corrections given under the head BAROMETER would be necessary, in order to render it equally perfect with observations by that instrument. In short, this method may be considered as a telltale on the barometer, showing where the barometer would stand if placed in its position. Thus, if water boil at 200° on the top of a mountain, that is merely to be considered as indicating that the barometer, if placed there, would stand at 22.8; after which, the process of deducing the height remains the same. To illustrate the mode of deducing heights from the boiling point, as we have given it, we take the following example.

Water boils on the top of Ben Nevis at 203.8° , while at the side of the Caledonian Canal it boils at 212° , the temperature being 30° on the summit of the mountain, and 35° below.

From 212°	To 30°
Take 203.8°	Add 35°
There remains 8.2°	Sum 65°
Multiply by 530	Subt. 64°
246.0	
410	Remain 1° mult. by 4.346
4346 first approx.	Latitude 56° nearly
4 first correct.	Mult. 4.350
	by 2.
4350 second approx.	
9.7 second correct.	9.700

Calc. height, 4359.7 third approximation.

4358. true measured height—the difference being less than 2 feet.

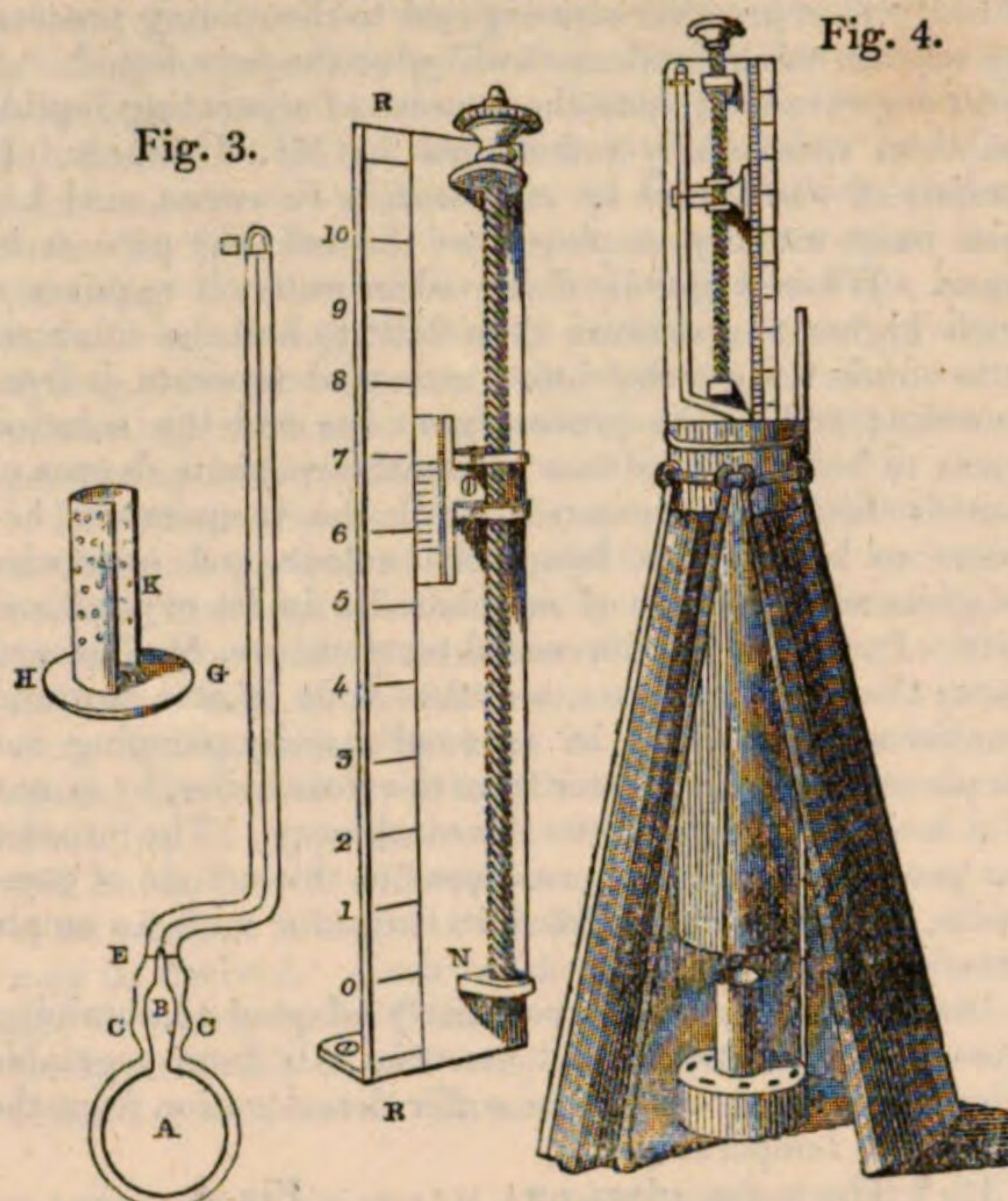
This method, however, is seldom susceptible of so high a degree of accuracy, even with the most carefully conducted experiments.

The Rev.
F. J. H.
Wollas-
ton's Appa-
ratus.

17. This method of determining heights by the ebullition of water is not a recent invention. It was suggested originally by Mr Fahrenheit, in the 33d volume of the *Philosophical Transactions*, in a paper entitled "*Barometri Novi Descriptio*." The subject was further matured by Cavallo, who has written concerning it in the 71st volume of the same Transactions; and the method has finally received from the Rev F. J. H. Wollaston the highest degree of perfection of which it seems to be capable. His paper, read before the Royal Society on the 6th of March, 1817, and afterwards published in the *Philosophical Transactions* of that year, gives an account of the very beautiful and ingenious apparatus which he has contrived for facilitating the procedure of taking the observations with the requisite precision. Fig. 4, is a view of the whole apparatus, consisting principally of a tripod stand, surrounded by a sort of tent cover, which is quite essential for the protection of the lamp from the strong winds generally encountered at considerable altitudes. The lamp acts on a small tin vessel, which is a cylinder $5\frac{1}{2}$ inches deep and $1\frac{1}{2}$ in diameter, the sides of which are double, leaving an interstitial space of confined air to prevent cooling. Above this vessel is a circular plate of metal G H K, to which the thermometer is to be fixed; and the scale and neck of the thermometer are seen projecting above the stand. A (fig. 3) represents the thermometer made use of, which it is desirable to have of as strong and as compact a construction as possible, while, at the same time, its degrees should range as extensively as possible. These desiderata are attained in his construction. The bulb A, one inch in diameter, is blown thick and strong, on the end of a tube about $\frac{1}{4}$ of an inch in diameter: close above the bulb, is a cavity B, swelled out to such a size as to contain whatever mercury will

expand out of the bulb, between 32° and the lowest temperature at which the mercury is likely to boil at such altitudes as it will be used to measure. It is this which renders the instrument compact; because, if it be not taken out of the British islands, it will never, in all pro-

Steam.



bability, boil at less than 200° ; and thus the whole length of the stalk is left for a range of 12° or 15° of the thermometer. In the instrument figured, the scale R is 5 inches long, $\frac{9}{10}$ of an inch wide, and a length 4.15 inches is divided into 100 parts, which, by a vernier reads off to 1000 parts, being 241 parts to an inch; so that 1° Fahr. corresponds to 233 parts on the scale, or to 530 feet. Each part of the scale, as read by the vernier, will therefore correspond to 2.275 feet, being about half the degree of minuteness of the mountain barometer divided into thousandths, each of which is nearly equivalent to one foot of height. The accuracy, however, of this scale is probably greater than the degree of accuracy of which the method of observation is itself capable.

Whether an observer have or have not the means of obtaining such an instrument as this, it will be, in many cases, useful to travellers to be provided with means, more or less accurate, of making observations of this nature, on the summit of such mountains as they may have the opportunity of visiting. For this purpose, the most convenient is a small cooking apparatus, such as will supply the wants of a traveller; consisting of a round tin stand, protecting a lamp, in which a small quantity of the traveller's supply of spirituous liquid may be burnt, so as to boil some of the water of a small bottle, which he has also carried with him, or perhaps a little melted snow. An umbrella or waterproof cloak will screen the whole from the wind; and a thermometer should have been procured, with a stem as minutely divided as possible, and should be inserted, by means of a small cork, in an aperture of the lid left on purpose. The quantity of the water may be small, and it will serve a culinary purpose immediately after the operation is completed. The thermometer should be inserted only among the steam. The traveller must take great precautions for striking a light, as he will find this much more troublesome in the cold rarified air of a mountain summit than below.

18. Distillation is a method of separating a liquid from extraneous matter, by first of all converting it into steam,

Directions
to travel-
lers.

Steam.
Distilla-
tion in
vacuo.

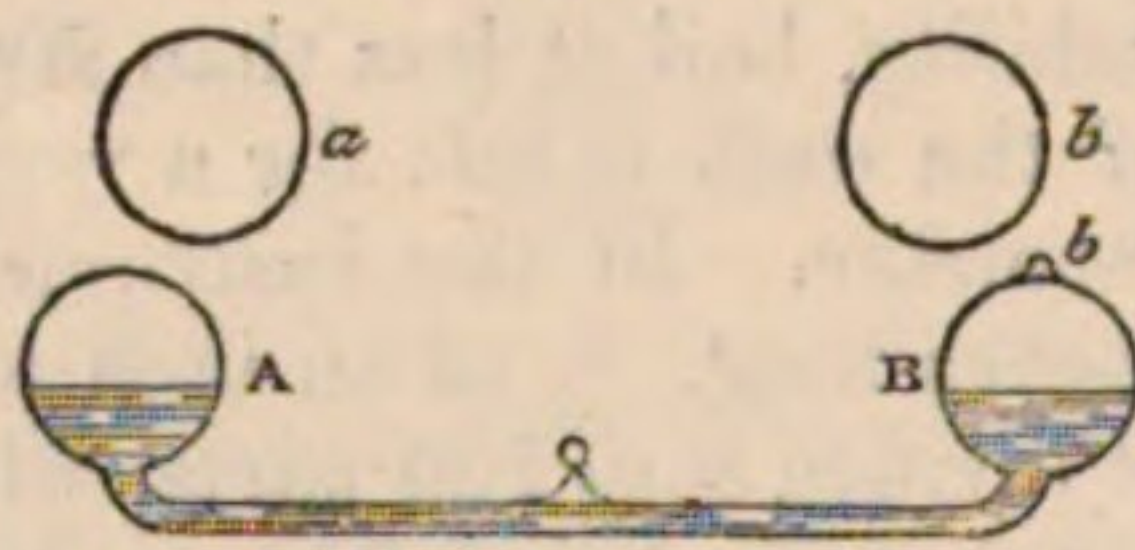
and then condensing that steam so as to form the liquid. Different substances take the liquid form at various temperatures; and, therefore, the heat may be so regulated that only one substance of a mixture shall take the form of vapour, and being conveyed by a pipe through a vessel of cold water, or otherwise exposed to the cooling process, the vapour being condensed will give the pure liquid. A great improvement upon the process of separating liquids has been successfully introduced by Mr. Howard. It consists of *distillation or evaporation in vacuo*, and has been most usefully employed in the refining process of sugar. When sugar is dissolved in water, it requires a much higher temperature than 212° to boil the mixture, or to convert the water into steam and separate it from the solid; and as the process goes on, and the solution comes to hold less and less water, the requisite degree of heat is further augmented, until the temperature becomes so high as to injure the colour and otherwise deteriorate the article of merchandise in its crystallized state. Instead of this increased temperature, Mr Howard places the syrup in vacuo, and thus boils it at a low and innoxious heat. This he accomplishes by pumping out the air and vaporized water from the close boiler, by means of a large air-pump driven by machinery. The process has produced a great improvement on this article of commerce, and has remunerated its inventor with an ample fortune.

Distillation in vacuo is peculiarly adapted to obtaining those delicate extracts and essential oils from vegetable substances, which are apt to suffer deterioration from the usual high temperatures.

The Pulse
Glass.

19. * The pulse glass, an invention attributed to Dr Franklin, is an apparatus illustrating beautifully the process of ebullition in vacuo at low temperatures. If two glass balls, A and B (fig. 5), be connected by a slender tube, and one of them, A, be filled with water, a small opening or pipe *b* being left at the top of the other, and this be made to boil, the vapour produced by it will drive all the air out of the other, and will at last come out itself, producing steam at the mouth of the pipe. When the ball B is observed to be occupied by transparent vapour, we may conclude that the air is completely expelled. Now, shut the pipe by sticking it into a piece of tallow or wax, the vapour in B will soon condense, and there will be a vacuum. The flame of a lamp and blow-pipe being directed to the little pipe *b*, will immediately cause it to close and seal hermetically. We have now a pulse glass. Grasp the ball A in the hollow of the hand; the heat of the hand will immediately expand the bubble of vapour which may be in it, and this vapour will drive the water into B, and then will blow up through it for a long while, keeping it in a state of violent ebullition, as long as there remains a drop or film of water in A. But care must be taken that B is all the while kept cold, that it may condense the vapour as fast as it rises through the water. Touching B with the hand, or breathing warm on it, will immediately stop the ebullition. When the water in A has thus been dissipated, grasp B in the hand; the water will be driven into A, and the ebullition will take place there as it did in B. Putting one of the balls into the mouth will make the ebullition more violent in the other, and the one in the mouth will feel very cold. This is a pretty illustration of the rapid absorption of the heat by the particles of water which are thus converted into elastic vapour. We have seen this little toy suspended by the middle of the tube like a balance, and thus placed in the inside of a window, having two holes, *a*, *b*, cut in the pane, in such a situation, that, when A is full of water and prepon-

Fig. 5.



derates, B is opposite to the hole *b*. Whenever the room became sufficiently warm, the vapour was formed in A and immediately brought the water into B, which was kept cool by the air coming into the room through the hole *b*. By this means B was made to preponderate in its turn, and A was then opposite to the hole *a*, and the process was now repeated in the opposite direction. This amusement continued as long as the room was warm enough. Instead of water, alcohol or ether may be substituted, and will act more readily.

20. The following experiment, where ebullition is produced by the application of cold, is instructive. A Florence flask F, is about $\frac{1}{3}$ full of water, and is placed over a lamp E until the water boils; and when the steam has been rising for a short time violently from the

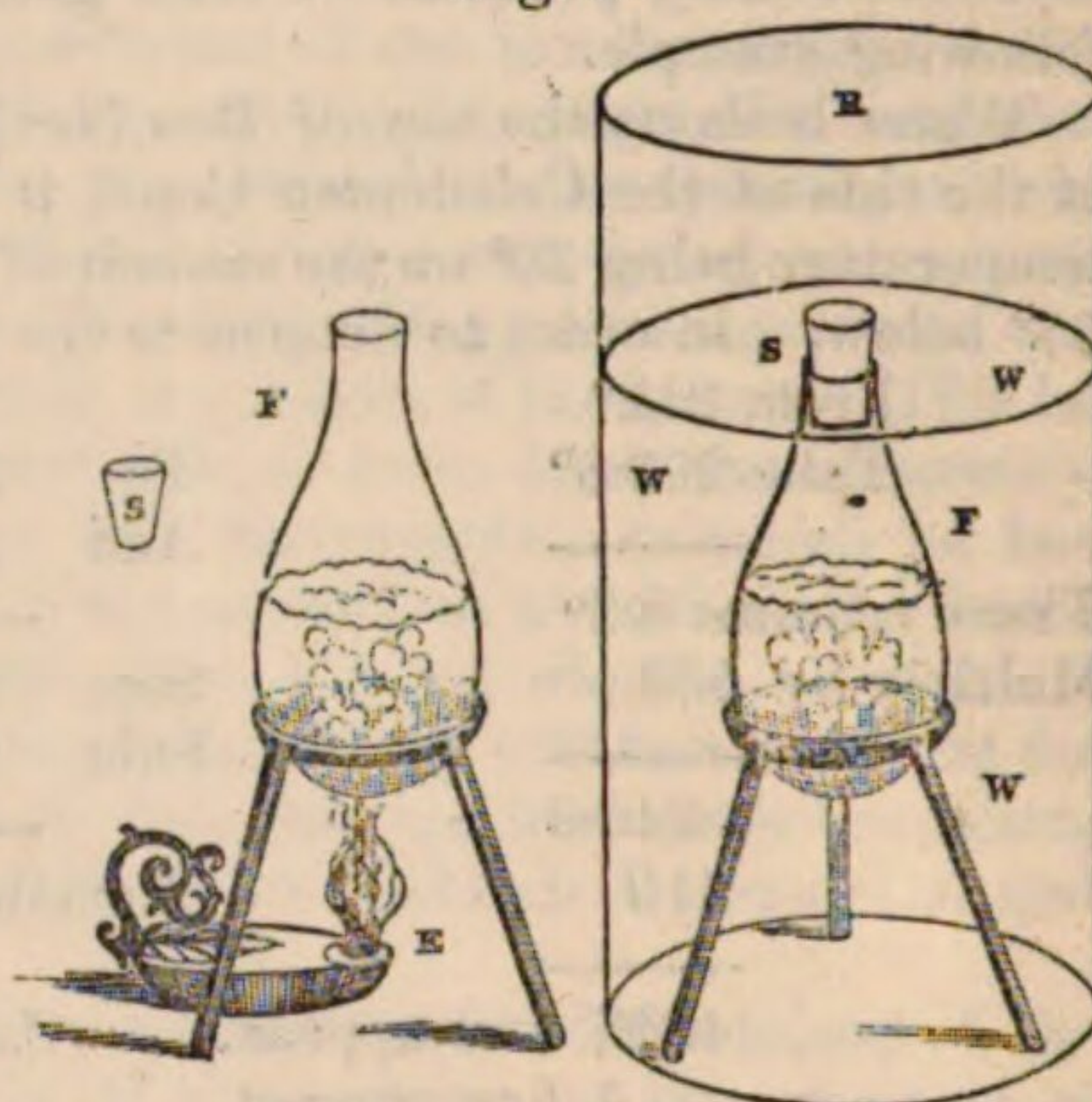
neck of the vessel, the cork S is to be applied as a stopper, and must fit with great accuracy. The flask thus closed is to be set aside for a few minutes till it have cooled considerably, and is then to be suddenly placed on a stand in the cold water W, contained in the glass reservoir R. The ebullition in the flask will recommence with a degree of violence proportioned to the coldness of the water W.

The theory of this action is simple. When the flask is plunged in the cold water, $\frac{2}{3}$ of its contents are steam: the chill water condenses it into water, it shrinks up into $\frac{1}{1728}$ th part of its bulk, and would leave 1727 parts out of 1728 vacuum; but the warm water being now in vacuo, throws up in rapid ebullition (according to Art. 14) copious volumes of vapour of its own temperature, which is again, by coming into contact with the sides of the vessel, and by directly giving off its heat to the water, chilled into water, and so in succession all the vapour thus sent up is in turn reconverted into water, and the vacuum sustained, until at last, the equilibrium between the temperature of the water, within and around the flask, having been established, the interchange of caloric ceases; and even now, if the flask were plunged into freezing water, the ebullition would recommence as violently as before.

21. We have already noticed (Art. 11.) the fact that, when water is confined in a close vessel, and heat is applied to it, the water will not boil even at a temperature of 212° . If heat be continually thrown into the water in this state, the particles will acquire a very high temperature; and, at the same time, the tendency of the enclosed fluid to burst the vessel will become very great. The following experiment upon this subject is one of the most interesting and the earliest of which we are in possession. It was published in 1663 by the Marquis of Worcester, and we give it in his own words. "I have taken a piece of a whole cannon, whereof the end was burst, and filled it three quarters full, stopping and screwing up the broken end, as also the touch-hole, and making a constant fire under it; within twenty-four hours it burst, and made a great crack."

It is in virtue of the great elastic force by which water, when heated, tends to expand into 1728 times its bulk, in the form of steam, that this element has become a mechanical mover, subject to the control of man. There are two great principles upon which such machines are con-

Fig. 6.



Ebullition
produced
by cold.

Force of
Steam con-
fined in
close ves-
sels.

Steam. structured; the one commonly called high-pressure steam-engines, and the other low-pressure steam-engines.

Applications of Steam. High-Pressure Steam-Engine. In a high-pressure steam-engine, the principal source of motion is the *elastic force* of steam, formed by water, raised to a high temperature in confined vessels, and tending to escape from them with such force, as to impart motion and movement to solids or fluids, ingeniously arranged to receive from it velocity or direction required for the accomplishment of some end.

Low-Pressure Condensing Steam-Engine. In a low-pressure steam-engine, the principal source of power is derived from using steam merely for the purpose of forming a vacuum. For this purpose steam is admirably calculated. It is only necessary to allow the steam of a liquid to enter any vessel filled with air; and if there be left an aperture of escape, the steam, entering in abundance, will push the air out before it. When the air has wholly escaped, it only remains necessary to close all the openings of the vessel, and allow it gradually to cool down, when the steam will be condensed, will shrivel up in the form of water into the 1728th part of its bulk, leaving the other 1727 parts vacuous. The mechanical force of a vacuum on the earth's surface is well known: it will raise water to a height of more than 30 feet, and support 15 lbs. on every square inch of surface exposed to it. Whatever, therefore, the formation of a vacuum on the earth's surface can effect, of that is the force of steam capable at low pressure, scarcely exceeding the temperature of 212°. Hence the low-pressure engine is sometimes called the condensing engine, because it acts principally by condensation of steam to form a vacuum. The high pressure of

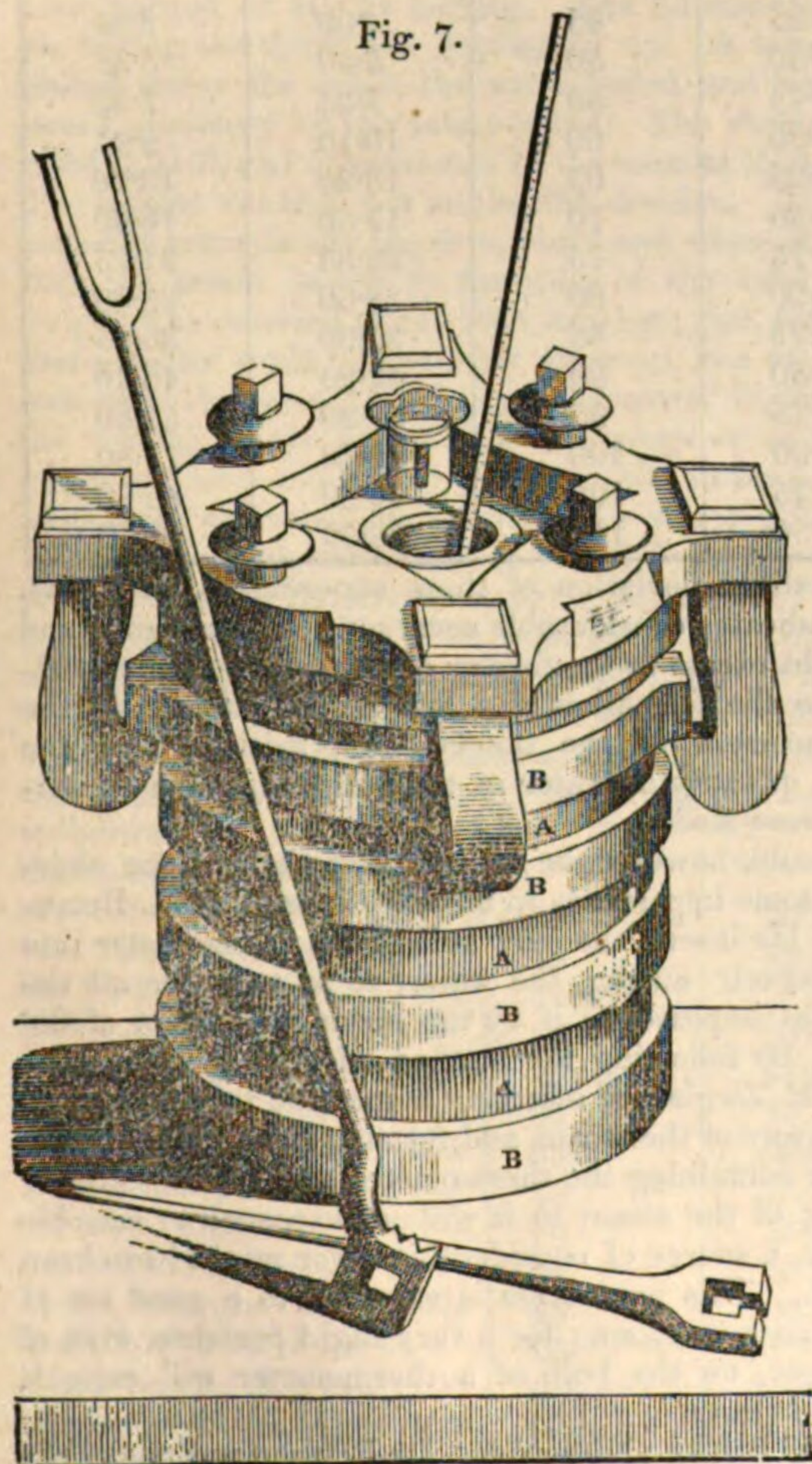
steam, and its vacuum-forming power, are frequently used in combination.

22. There are other properties of steam, besides its mechanical force, that render its use of great practical value. Its great capacity for heat enables it to take up, at one time, and in one place, a large quantity of heat, which it may be employed as a vehicle to transfer, at a subsequent period and at a distant point, to some other substance. It is thus rendered an economizer and distributor, a reservoir of heat derived from the combustion of fuel. In this view it has great value as an agent in distributing the heat used for warming buildings, heating baths, evaporating solutions, distilling, brewing, drying, dyeing, and even for domestic cookery, and the means of extracting wholesome and nutritious food from most unpromising and unpalatable materials.

In order, however, to its successful application as a mechanical power, and its profitable use in each of the various functions which it is capable of performing, it is necessary to study its various phenomena in greater detail; to obtain an intimate acquaintance with its properties; to determine its laws in the various relations of space, time, and quantity; how much heat it requires, what fuel it consumes, what force it exerts, how fast it will move, how it will condense, expand, and contract, and what relation it bears to the different fluids from which it may be derived. Each of these enquiries, and the manner in which each of these objects may be most satisfactorily attained, is the subject of one or other of the following sections of this article.

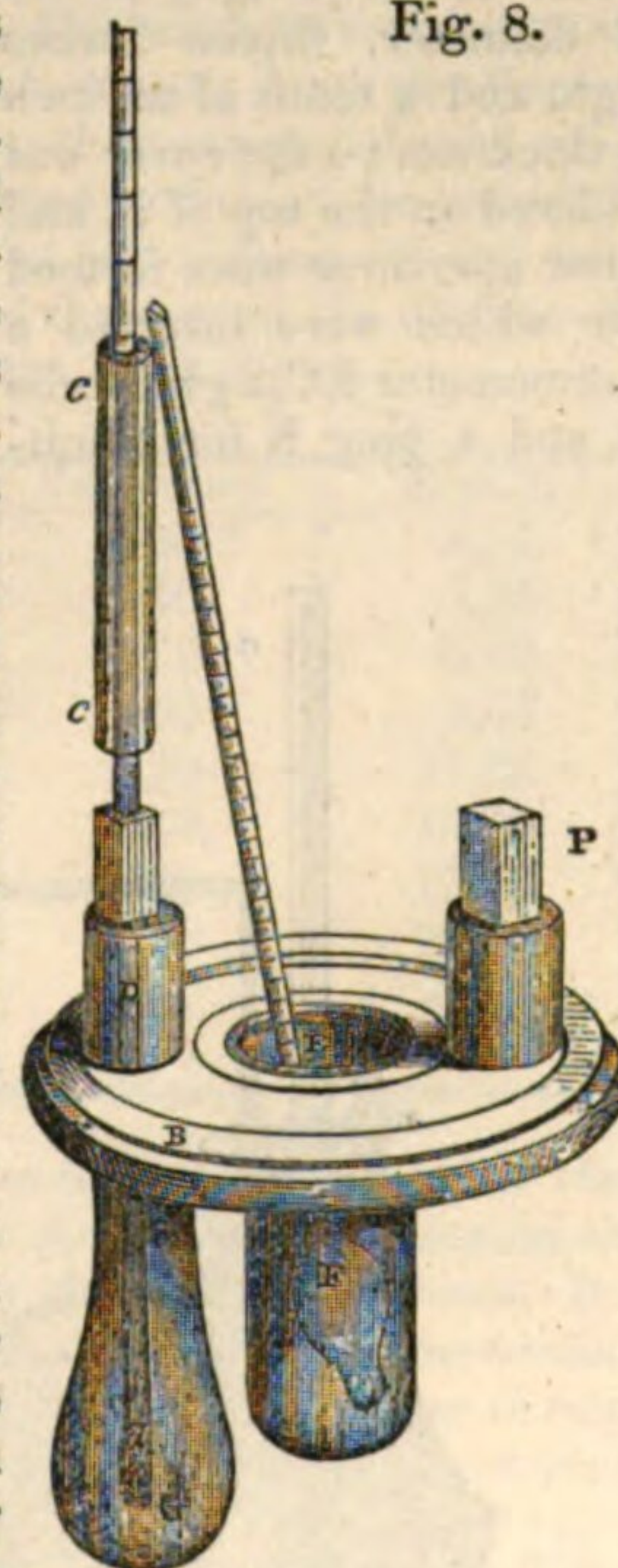
Jean Henri SECT. II.—EXPERIMENTAL RESEARCHES CONCERNING THE ELASTIC FORCE OF STEAM AT DIFFERENT TEMPERATURES. Ziegler's Experiments.

Fig. 7.



VOL. XX.

Fig. 8.



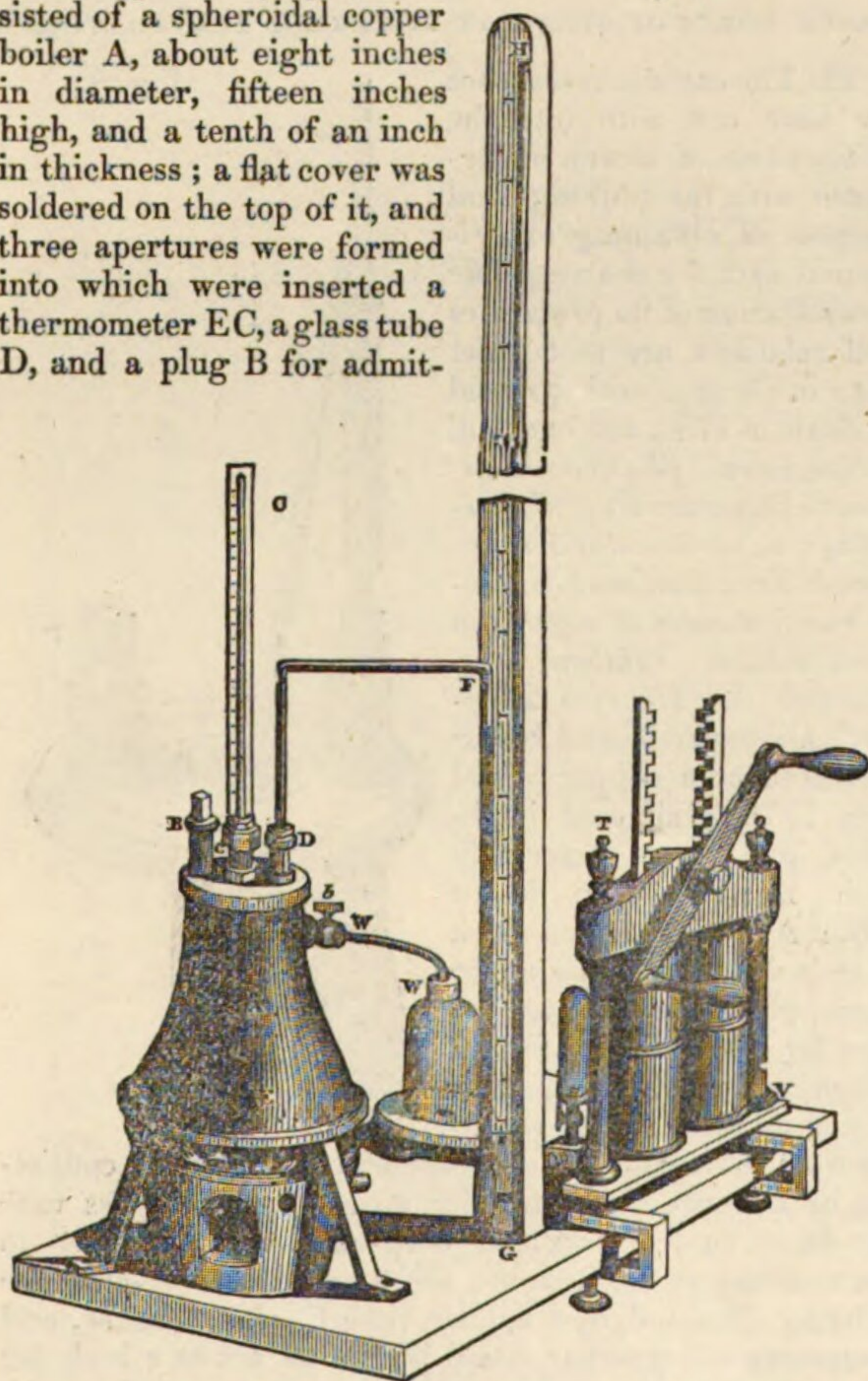
23. The earliest researches we have met with into the phenomena of steam, undertaken with the philosophical purpose of obtaining experimental data for the scientific investigation of its properties and relations, are to be met with in a scarce work, printed at Basle in 1769, and entitled, "*Specimen physico-chemicum de Digestore Papini; primitias experimentorum novorum circa fluidorum a calore rarefactionem et vaporem elasticitatem exhibens, &c. Auctore Jo. Henrico Ziegler.*" His experimental boiler consisted of a copper vessel (fig. 7) AA, silvered internally, and belted externally with massive iron hoops BB. A strong frame-work of iron, attached to the upper hoop, gives support to the circular cover B, (fig. 8,) in which there are an opening P for admitting water, another D into which an elaterometer is inserted, consisting of a bottle G, containing mercury, and a glass tube c c cased in iron, open at both ends, and immersed in the mercury at the bottom; the third or central aperture E being occupied by a copper tube F, closed below, and containing oil or other viscid liquid, to act as a bath for the bulb of the thermometer F and its protector from the pressure of the vapour. The method of using this apparatus was as follows. The digester being partly filled with water, closed and placed on the fire, the generation of the steam would raise the oil or mercury in the bath

4 D

Steam. (E) to the temperature of the water and steam within, so as to give to the thermometer F an indication of the temperature; and, at the same time, the elastic force of the steam flowing or moving by would raise it in C to a certain number of inches, so as to cause the corresponding pressure. This apparatus is both appropriate and ingenious, and indicates considerable mechanical knowledge in its inventor, a physician of Winterthour in Switzerland. Unhappily he lived too remote from the scene of the philosophical discoveries of that period, to adopt the precautions necessary to give value to his experiments. He allowed atmospheric air to mingle with the steam to such an extent as greatly to vitiate his results.

M. Betancourt's Experiments. 24. M. Betancourt visited England about the end of last century; and having been employed to select machines, models, and drawings for the Spanish government, made himself acquainted with the use of steam in Great Britain at that period. On his return, he immediately undertook a series of experiments on the force of the vapour of water, alcohol, and other liquids, at various temperatures. His apparatus is tolerably perfect; and the precautions which he adopted for the removal of atmospheric air from intermixture with the vapour, give his experiments considerable value and precision. Some of his experiments were made in vacuo; and he seems to have been one of the first philosophers who examined the production of steam at temperatures below the ordinary point of ebullition, under the pressure of the atmosphere. His experiments extend from 32° up to 279°, being 67° above the ordinary boiling point.

His apparatus (Fig. 9) consisted of a spheroidal copper boiler A, about eight inches in diameter, fifteen inches high, and a tenth of an inch in thickness; a flat cover was soldered on the top of it, and three apertures were formed into which were inserted a thermometer EC, a glass tube D, and a plug B for admit-



ting water. The glass tube being bent downwards at F, was recurved upwards at G, leaving an upright stem, ten feet high, and hermetically sealed at the top, so as to leave a perfect vacuum in that end of the tube, over a column of mercury of about 30 inches in the two

branches of the recurvation at the bottom. The boiler was provided with a stop-cock *b*, by which the air was extracted from the boiler previous to experiment, by means of an air-pump TV, communicating with W; and when this was accomplished so as to obtain a vacuum on both ends of the mercurial column, the mercury stood, as in the figure, on nearly the same level in both its branches. The fire was instantly applied, and the crackling noise which followed informed him that the ebullition had commenced, and the steam in the boiler pressing on that end of the mercurial column nearest to it, raised the other in the vacuum a certain quantity above its outer level, indicating its elastic force, which gradually increased until it became at the usual heat of boiling water, equal to twenty-eight French inches, the mean pressure of the atmosphere. The following table will enable us to estimate the value of these experiments; it is given in degrees of Reaumur's thermometer, of which 0° coincides with 32° of our common scale, and 80° with our boiling point 212° Fahrenheit, each degree of Reaumur being equal to $\frac{2}{3}$ of our scale. The pressure is in French inches of mercury:—

Degrees of Fahrenheit.	Reaumur's Scale.	First Series of Observations.	Second Series of Observations.
		Inches of Mercury.	Inches of Mercury.
32°	0°	0·0	0·0
43·25	5	0·05	0·02
54·50	10	0·17	0·15
65·75	15	0·35	0·35
77·00	20	0·62	0·65
88·25	25	1·00	1·05
99·50	30	1·50	1·52
110·75	35	2·12	2·15
122·00	40	2·90	2·92
133·25	45	4·00	3·95
144·50	50	5·50	5·35
155·75	55	7·55	7·32
167·00	60	10·10	9·95
178·25	65	13·25	13·20
189·50	70	17·50	16·90
200·75	75	22·35	21·75
212·00	80	28·60	28·00
223·25	85	37·00	36·45
234·50	90	47·20	46·40
245·75	95	58·20	57·80
257·00	100	72·40	71·80
268·25	105	84·90	86·80
279·50	110	98·00	98·00

The slight deviation of these experiments from each other indicates considerable accuracy of experiment; and the slight excess in the former of the two series is attributed to the formation of a less perfect vacuum at the commencement of the observations, arising from the smaller quantity of water in the boiler when the experiments were made.

It should, however, be noticed, that there is one omission of some importance in the experiments of M. Betancourt. He inserts the *bare bulb* of his thermometer into the reservoir among the water, so as to suffer all the variations imposed on it by the varying elasticity of the steam. By following the method adopted by his predecessor, M. Ziegler, of inserting a metallic tube to sustain the pressure of the steam, and forming it into a mercurial bath for containing the thermometer, and so transmitting the heat of the steam to it without exposure to variable pressure, a source of considerable error might have been avoided. This precaution is essential to a good set of experiments on steam; for a very slight pressure, even of the finger, on the bulb of a thermometer will raise it several degrees.

25. Of British philosophers, Dr Robison was one of the first to make accurate and systematic experiments on the

Steam.
M. Betancourt's Experiments.

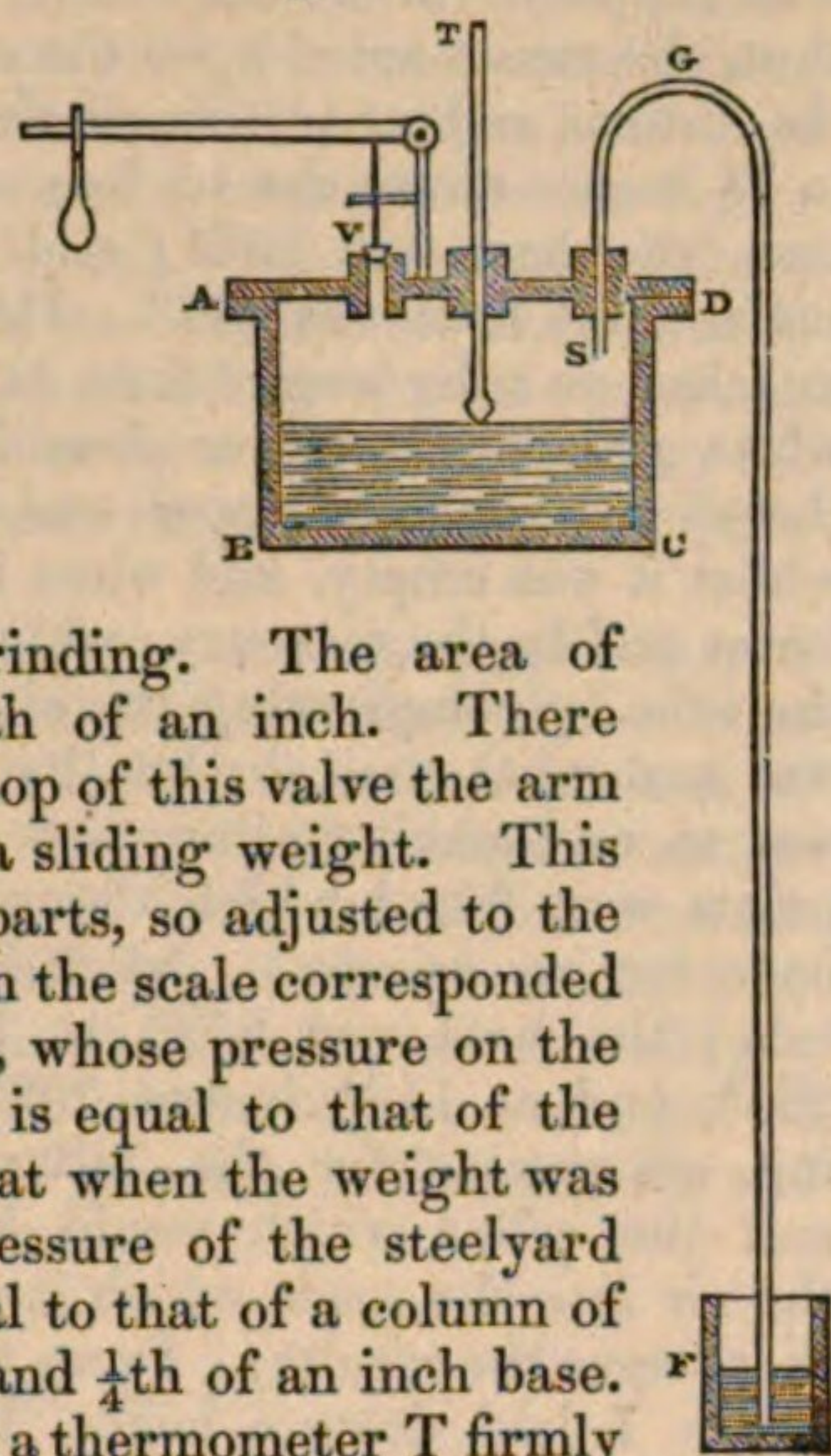
Steam. phenomena of the temperature and elastic force of steam. They appear to have been made in 1778. His apparatus is represented in the accompanying figure.

Dr Robi-
son's Ex-
periments.

* ABCD (Fig. 10.) is the section of a small digester made of copper. Its lid, which was fastened to the body with screws, was pierced with three holes, each of which had a small pipe soldered into it. The first hole was furnished with a brass safety-valve V, nicely fitted to it by grinding. The area of this valve was exactly $\frac{1}{4}$ th of an inch. There rested on the stalk at the top of this valve the arm of a steel-yard carrying a sliding weight. This arm had a scale of equal parts, so adjusted to the weight, that the number on the scale corresponded to the inches of mercury, whose pressure on the under surface of the valve is equal to that of the steelyard on its top; so that when the weight was at the division 10, the pressure of the steelyard on the valve was just equal to that of a column of mercury 10 inches high, and $\frac{1}{4}$ th of an inch base. The middle hole contained a thermometer T firmly fixed into it, so that no vapour could escape by its sides. The ball of this thermometer was but a little way below the lid. The third hole received occasionally the end of a glass pipe SGF, whose descending leg was about 36 inches long. When this syphon was not used, the hole was properly shut with a plug.

* The vessel was half filled with distilled water which had been purged of air by boiling. The lid was then fixed on, having the third hole S plugged up. A lamp being placed under the vessel, the water boiled, and the steam issued copiously by the safety-valve. The thermometer stood at 213°, and a barometer in the room at 29.9 inches. The weight was then put on the fifth division. The thermometer immediately began to rise; and when it was at 220, the steam issued by the sides of the valve. The weight was removed to the 10th division; but, before the thermometer could be distinctly observed, the steam was issuing at the valve. The lamp was removed further from the bottom of the vessel, that the progress of heating might be more moderate; and when the steam ceased to issue from the valve, the thermometer was at 227. The weight was now shifted to 15; and, by gradually approaching the lamp, the steam again issued, and the thermometer was at 232 $\frac{1}{2}$. This mode of trial was continued all the way to the 75th division of the scale. The experiments were then repeated in the contrary order; that is, the weight being suspended at the 75th division, and the steam issuing strongly at the valve, the lamp was withdrawn, and the moment the steam ceased to come out, the thermometer was observed. The same was done at the 70th, 65th division, &c. These experiments were several times repeated both ways; and the means of all the results for each division are expressed in the subjoined table, where column 1st expresses the elasticity of the steam, being the sum of 29.9; and the division of the steelyard, column 2d, expresses the temperature of the steam corresponding to this elasticity.

Fig. 10.



* A very different process was necessary for ascertaining the elasticity of the steam in lower temperatures, and consequently under smaller pressures than that of the atmosphere. The glass syphon SGF was now fixed into its hole in the lid of the digester. The water was made to boil smartly for some time, and the steam issued copiously both at the valve and at the syphon. The lower end of the syphon was now immersed into a broad saucer of mercury, and the lamp instantly removed, and every thing was allowed to grow cold. By this the steam was gradually condensed, and the mercury rose in the syphon, without sensibly sinking in the saucer. The valve and all the joints were smeared with a thick clammy cement, composed of oil, tallow, and rosin, which effectually prevented all ingress of air. The weather was clear and frosty, and the barometer standing at 29.84, and the thermometer in the vessel at 42°. The mercury in the syphon stood at 29.7, or somewhat higher, thus showing a very complete condensation. The whole vessel was surrounded with pounded ice, of the temperature 32°. This made no sensible change in the height of the mercury. A mark was now made at the surface of the mercury. One observer was stationed at the thermometer, with instructions to call out as the thermometer reached the divisions 42, 47, 52, 57, and so on by every five degrees till it should attain the boiling heat. Another observer noted the corresponding descents of the mercury by a scale of inches, which had its beginning placed at 29.84 from the surface of the mercury in the saucer.

* The pounded ice was now removed, and the lamp placed at a considerable distance below the vessel, so as to warm its contents very slowly. These observations being very easily made, were several times repeated, and their mean results are set down in the following table: only observe, that it was found difficult to note down the descents for every fifth degree, because they succeeded each other so fast. Every 10th was judged sufficient for establishing the law of variation. The first column of the table contains the temperature, and the second the descent (in inches) of the mercury from the mark 29.84.

Temperature.	Elasticity.	Temperature.	Elasticity.
32 °	0.0	130 °	3.95
40	0.1	140	5.15
50	0.2	150	6.72
60	0.35	160	8.65
70	0.55	170	11.05
80	0.82	180	14.05
90	1.18	190	17.85
100	1.61	200	22.62
110	2.25	210	28.65
120	3.00		

Four or five numbers at the top of the column of elasticities, are not so accurate as the others, because the mercury passed pretty quickly through these points. But the progress was extremely regular through the remaining points; so that the elasticities corresponding to temperatures above 70° may be considered as very accurately ascertained.

* Not being altogether satisfied with the method employed for measuring the elasticity in temperatures above that of boiling water, a better form of experiment was adopted. Indeed it was the want of other apparatus which made it necessary to employ the former. A glass tube was procured of the form represented in Fig. 11, having a little cistern L, from the top and bottom of which proceeded the syphons K and MN. The cistern contained mercury, and the tube MN was of a slender bore, and was about six feet two inches long. The end K was firmly fixed in the third hole of the lid, and the long leg of the syphon was furnished with a scale of inches, and firmly fastened to an upright post.

Elasticity.	Temperature.
35 inches.	209 °
40	226
45	232
50	237
55	242
60	247
65	251
70	255
75	259
80	263
85	267
90	270 $\frac{1}{2}$
95	274 $\frac{1}{2}$
100	278
105	281

Steam.
Dr Robi-
son's Ex-
periments.

Steam.
Dr Robi-
son's Ex-
periments.

The lamp was now applied at such a distance from the vessel as to warm it slowly, and make the water boil, the steam escaping for some time through the safety-valve. A heavy weight was then suspended on the steelyard; such as it was known that the vessel would support, and, at the same time, such as would not allow the steam to force the mercury out of the long tube. The thermometer began immediately to rise, as also the mercury in the tube MN. Their correspondent stations are marked in the following table.

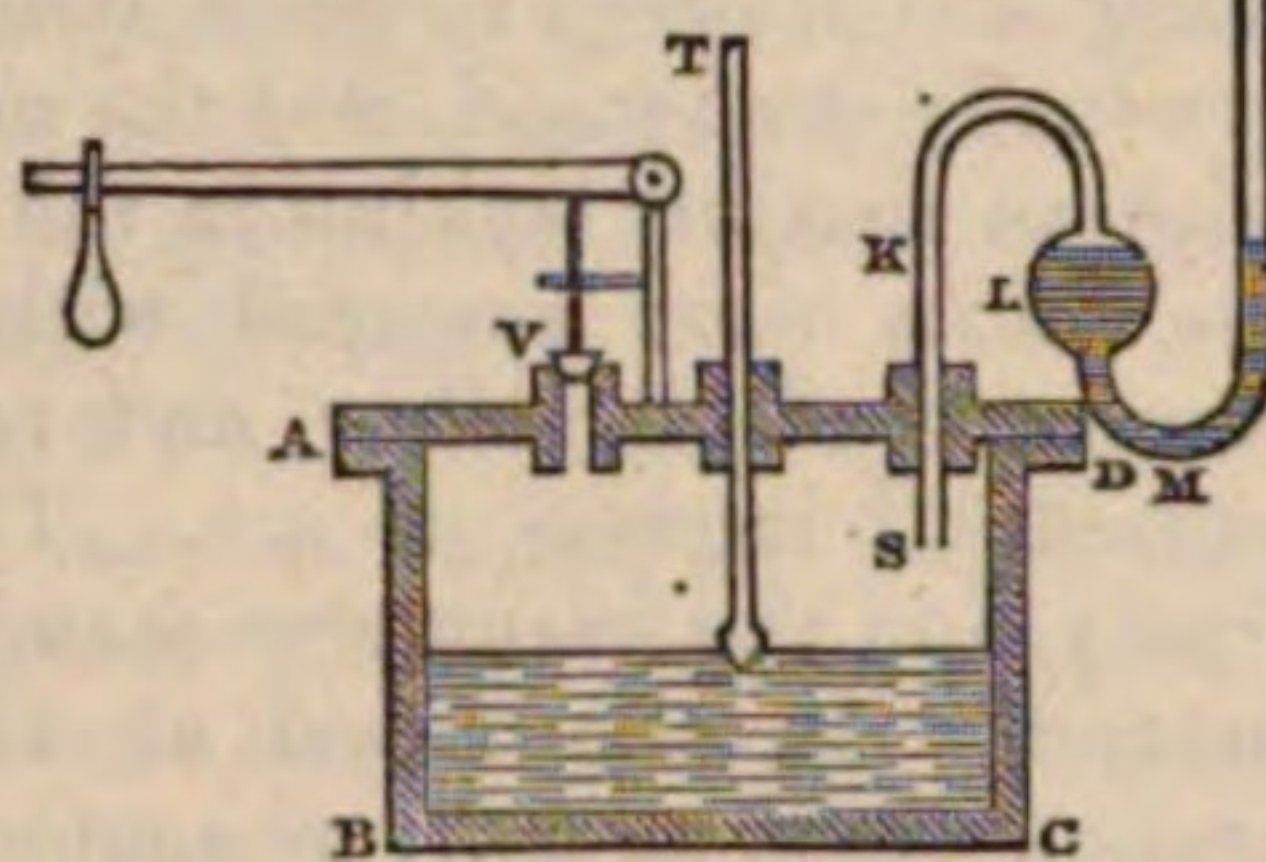


Fig. 11.

Temperature.	Elasticity.
212°	0.0
220	5.9
230	14.6
240	25.0
250	36.9
260	50.4
270	64.2
280	76.0

This form of the experiment is much more susceptible of accuracy than the other, and the measures of elasticity are more to be depended on. In repeating the experiment, they were found much more constant; whereas, in the former method, differences occurred of two inches and upwards.

* We may now connect the two sets of experiments into one table, by adding to the numbers in this last table the constant height 29.9, which was the height of the mercury in the barometer during the last set of observations.

Temperature.	Elasticity.	Temperature.	Elasticity.
32°	0.0	160	8.65
40	0.1	170	11.05
50	0.2	180	14.05
60	0.35	190	17.85
70	0.55	200	22.62
80	0.82	210	28.65
90	1.18	220	35.8
100	1.6	230	44.5
110	2.25	240	54.9
120	3.0	250	66.8
130	3.95	260	80.3
140	5.15	270	94.1
150	6.72	280	105.9

Mr Watt's
Experi-
ments.

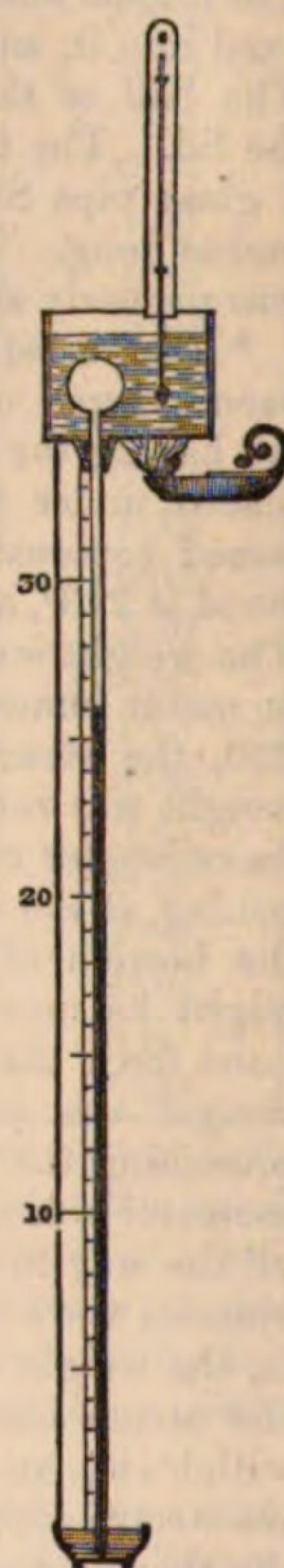
26. In the mean time, however, Mr Watt had been led, in the course of his invention of the steam-engine, to make experiments on the elastic force of steam, of which he has given the following account, and which was annexed by himself to Dr Robison's original article in this work.

† In the winter of 1764-5, I made experiments at Glasgow on the subject, in the course of my endeavours to improve the steam-engine, and as I did not then think of any simple method of trying the elasticities of steam at temperatures less than that of boiling water, and had at hand a digester by which the elasticities at greater heats could be tried, I considered that, by establishing the ratios in which they proceeded, the elasticities at lower heats might be found nearly enough for my purpose. I therefore fitted a thermometer to the digester, with its bulb in the inside, placed a small cistern with mercury also within

the digester, fixed a small barometer tube with its end in the mercury, and left the upper end open. I then made the digester boil for some time, the steam issuing at the safety-valve, until the air contained in the digester was supposed to be expelled. The safety-valve being shut, the steam acted upon the surface of the mercury in the cistern, and made it rise in the tube. When it reached to 15 inches above the surface of the mercury in the cistern, the heat was 236°; and at 30 inches above that surface, the heat was 252°. Here I was obliged to stop, as I had no tube longer than 34 inches, and there was no white glass made nearer than Newcastle-upon-Tyne. I therefore sealed the upper end of the tube hermetically, whilst it was empty, and when it was cool immersed the lower end in the mercury, which now could only rise in the tube by compressing the air it contained. The tube was somewhat conical; but, by ascertaining how much it was so, and making allowances accordingly, the following points were found, which, though not exact, were tolerably near for an *aperçu*. At 29½ inches (with the sealed tube) the heat was 252°, at 75½ inches the heat was 264°, and at 110½ inches 292°. (That is, after making allowances for the pillar of mercury supported, and the pillar which would be necessary to compress the air into the space which it occupied, these were the results). From these elements I laid down a curve, in which the abscissæ represented the temperatures, and the ordinates the pressures, and thereby found the law by which they were governed, sufficiently near for my then purpose. It was not till the years 1773-4, that I found leisure to make further experiments on this subject, of which, though I do not consider the results as accurate, I shall give an account here, as they were in point of date prior to any others that I was then acquainted with.

† A tin pan, of about five inches in diameter and four inches deep, had a hole made in its bottom, near one side, and in this hole was soldered a socket somewhat conical, which nearly fitted a barometer tube with which the experiments were to be made. This tube was about 36 inches long, and had a ball at one end about 1½ inches diameter, the contents of which were nearly equal to those of the stem of the tube; some paper was lapped round the tube near the ball, and it was forced tight into the conical socket of the pan, so that the ball was within the latter, at such a height that it might be immersed in water. The tube and pan were then inverted, and the ball was filled with clean mercury, and the stem with distilled water fresh boiled. The tube was re-inverted, so that the ball and pan were uppermost; the lower end of the tube being shut by the finger, the water ascended into the ball, and the mercury occupied the tube. The lower end of the latter being then placed in a cistern of mercury, and released from the finger, the mercury and water descended, and the ball was left partly empty: being agitated in this position, and let stand some time, much air was extricated from the water; the tube was inclined as much as it could be, and again inverted, the air let out, and its place supplied with boiling water. It was again placed with the ball uppermost, the end of the tube stopped, the pan filled with hot water which was made to boil by means of a lamp, the lower end of the tube being

Fig. 12.



Steam.
Mr Watt's
Experi-
ments.

Steam. placed in the cistern, and released from the finger, the mercury descended into the cistern, but upon the water Mr Watt's in the pan being suffered to cool, partly rose again into the tube. Much air was thus liberated, and more was got rid of by agitation, in the manner of the water-hammer, and by leaving it standing for some time erect, until at last I got it so free from air, that when I raised it upright, it supported a column of mercury 34 inches high; and no vacuum was formed until it was violently shaken, when it fell down suddenly and settled at 28.75 inches, but upon being inclined, a speck of air always remained, though, when it was expanded by a pillar of mercury 27 inches high, this speck was not larger than a pin's head.

† In this state, when the tube was perpendicular, I found the mercury to stand at 28.75 inches, the column of water above it was about $6\frac{1}{2}$ inches, = half an inch of mercury. The whole then being 29.25 inches, when the stationary barometer stood at 29.4, the difference, or pillar supported by the elasticity of the steam = 0.15 inch. The water in the pan was then heated exceedingly slowly by a lamp, and stirred continually by a feather to make the heat as equal as possible. The results are shown in the following table:—

TABLE No. I.

Heats.	Elasticities.	Heats.	Elasticities.	Heats.	Elasticities.	Heats.	Elasticities.
	Inches.		Inches.		Inches.		Inches.
55°	0.15	135°	4.53	167°	11.07	187°	17.51
74	0.65	142	5.46	172	11.95	189	18.45
81	0.80	148	6.40	175	12.88	191	19.38
95	1.30	153	7.325	177.5	13.81	193.5	20.34
104	1.75	157	8.25	180	14.73	196.5	21.26
118	2.68	161	9.18	182.5	15.66		
128	3.60	164	10.10	185	16.58		

At this time (1774) I tried a set of experiments in the same manner on a saturated solution of common salt. When this solution was perfectly saturated by boiling, and was put into the tube, it precipitated a quantity of salt which disturbed the experiment. I was therefore obliged to take it out, and filter it, during which process it attracted moisture from the air, and appeared, by its boiling point, not to be perfectly saturated. Though it was more free from air than water is, yet it parted from what it contained with great difficulty, and would part with none when shaken as a water-hammer, though it opened in all parts of the liquor. The result of this experiment is contained in the annexed table:—

TABLE No. II.—Stationary Barometer, 29.5.

Heats.	Elasticities.	Heats.	Elasticities.	Heats.	Elasticities.	Heats.	Elasticities.
	Inches.		Inches.		Inches.		Inches.
46°	0.01	154°	5.36	187°	12.67	208°	20.86
76	0.36	160	6.27	193.5	14.5	210	21.8
85	0.58	165	7.2	195.5	15.34	212	22.74
92	0.81	169	8.12	198.5	16.25	214	23.66
113	1.72	173	9.03	201.5	17.16	216	24.6
129	2.63	177	9.94	203.5	18.1	218	25.52
139	3.54	180	10.85	205.5	19.03	220	26.5
147	4.45	183	11.76	207	19.94		

In the same manner I tried a set of experiments upon spirit of wine, the results of which are contained in the annexed table:—

TABLE No. III.

Heats.	Elasticities.	Heats.	Elasticities.	Heats.	Elasticities.	Heats.	Elasticities.	Mr Watt's Experiments.
	Inches.		Inches.		Inches.		Inches.	
34°	0.22	120°	7.12	146.5°	15.03	164°	22.59	
40	0.929	124.5	8.46	148.5	15.974	166	23.53	
67	1.897	128	9.4	151	16.908	167	24.47	
84	2.806	132	10.34	152.5	17.85	168	25.4	
95	3.744	135	11.32	155	18.8	169	26.35	
103	4.728	139	12.21	157	19.75	171	27.3	
110	5.63	141.5	13.15	160	20.71	Stat. Bar.	29.4	
114	6.58	144	14.1	162.5	21.65			

Upon considering the probable cause of the difference, especially in the lower heats, between my experiments and those of Mr Southern, related in his letter annexed to this essay, I can only reconcile them by supposing that the stationary barometer, with which the comparison was made, had its scale placed 0.2 of an inch too low, and by adding that quantity to the elasticities in table 1st, they approach nearly to Mr Southern's experiments.

If that conjecture is adopted, the same addition will be necessary to tables 2d and 3d, as they were compared with the same stationary barometer.

To determine the heats at which water boils when pressed by columns of mercury above 30 inches, a tube of 55 inches long was employed; one end was put through a hole in the cover of a digester, and made tight by being lapped round with paper, and within the digester the end of the tube was immersed in a cistern of mercury. A thermometer was fixed in another opening, so that the bulb was in the inside of the digester, and the stem and scale without; and the bulb was kept half an inch from the cover of the digester by a wooden collar. The cover being fixed on tight, and the digester half filled with water, it was heated by means of a large lamp.

† The air in the upper part of the digester expanding by heat, the column of mercury in the tube was considerably raised by that expansion before the water boiled. The air was let out, and the water heated to boiling; still, however, some air remained, for the mercury stood at $213\frac{1}{2}$ °. That deduction being made, the following table shows the heats and corresponding elasticities.

Heats.	Elasticities.	Heats.	Elasticities.	Heats.	Elasticities.	Heats.	Elasticities.
213°	30	228°	39	240°	49	259°	66
215	31	229.5	40	242.5	50	261	68
217	32	231	41	244.5	52	262.5	70
219	33	232.5	42	247	54	264.5	72
220.5	34	234	43	248.5	56	266.5	74
222	35	235	44	250.5	58	268	76
223.5	36	236.5	45	252.5	60	269.5	78
225	37	237.5	46	255	62	271	80
226.5	38	238.5	47	257	64	272.5	82

In making these experiments, the digester was heated very slowly, and the heat was kept stationary as much as was possible at each observation, so that the whole series occupied some hours. The degrees of elasticity were observed by my friend Dr Irvine, whilst I observed those of the thermometer in all these experiments.

With the whole of the observations, I was, after all, by no means satisfied, as I perceived there were irregularities in the results which my more urgent avocations did not permit me to explore the causes of and to correct.

The matter remained in that state till 1796, when I requested Mr Southern to try them over again, in the

Steam.
Mr Watt's
Experi-
ments.

performance of which he was assisted by Mr William Creighton. The results of these observations are contained in Mr Southern's letter to me, which follows this memoir; and, from the very great care with which the experiments were made, the known accuracy of both Mr Southern and Mr Creighton, and the agreement of the experiments with one another, I have reason to believe them as nearly perfect as the subject admits of. The method he adopted of trying the elasticities above the temperature of boiling water by a piston, accurately fitted to a cylinder, is much to be preferred to that adopted by Dr Robison, and is more manageable under great elasticities than that of a long pillar of mercury.

Mr South-
ern's Ex-
periments.

27. The reference which is here made applies to the following letter from Mr Southern* to Mr Watt:—

"DEAR SIR,—The experiments of which the particular circumstances are hereafter related, were made in 1803, with the view of ascertaining chiefly the density of steam raised from water under different pressures above that of the atmosphere, an apparatus having then been made for a different purpose, which seemed pretty well adapted to this object.

"Besides the experiments now to be related, in which the temperature of steam raised under *high* pressures was observed in 1803, others had been made some years before, in 1797 and 98, for that purpose only; and, as they were made with the greatest circumspection, both the manner of making them and their results may be here described, as may also the results of other experiments, made with equal care, to ascertain the temperature of steam raised under *low* pressures.

"The instrument used in the former was a Papin's digester, similar to what you had used; the leading differences being in adapting a metallic tube to it to contain the thermometer, or rather as much of it as contained mercury, in the manner mentioned in the beginning of this letter, and instead of a valve, by the load on which to measure the elasticity of the contained steam, a nicely bored cylinder was applied, with a piston fitting it, so as to have very little friction, and to the rod of this was applied a lever, constructed to work on edges like those of a scale-beam, by which the resistance against the elastic force of the steam could be accurately determined; and at your suggestion, to be assured that no inaccuracy had crept into the calculation, by which this resistance, through the medium of the lever, was ascertained, an actual column of mercury of 30 inches high was substituted, and the correspondence was found to be within $\frac{1}{100}$ of an inch.

"The observations at each of the points of pressure noted were continued some minutes, the temperature at each being alternately raised and lowered, so as to make the pressure of the steam on the under side of the piston alternately too much and too little for the weight with which it was loaded; and thence a mean temperature was adopted, the extremes of which were, as well as I now recollect, not more than half a degree on each side of it. The load on the piston, including its own weight, &c., &c., was calculated to be successively just equal to 1, 2, 4, and 8 atmospheres of 29.8 inches of mercury each, and the temperature of the steam was varied as above till that of each point was determined; the results were thus:—

Atmospheres.	Pressure in inches of Mercury.	Temperatures.
1	29.8	212°
2	59.6	250.3
4	119.2	293.4
8	238.4	343.6

"The experiments for ascertaining the temperature of steam below the atmospheric pressure were made with an apparatus essentially similar to that which you originally used, and with scrupulous care and attention: and I met with the same incidents as you had done; such as, the production of a bubble of air whenever, after any experiment, the tube was inclined to refill the ball; and also the extraordinary suspension of a column of mercury of 35 inches vertical height, and of 7 inches of water above that, although the counterpoise was only that of the atmosphere, then under 30 inches. I found also that the tube required a considerable degree of tabouring or shaking to make the column subside and leave a space in the ball. This phenomenon was not produced till after much pains taken in inverting and re-inverting the tube again and again, nor till it had been suffered, after these operations, to stand for three or four days undisturbed in the exhausting position, and then discharging the air that had been accumulating in the interval.

"The results to be found in the table below, were deduced from the observations as you had done—viz., by adding to the height of the column of mercury in the tube (ascertained by a gauge floating on the surface of the mercury in the basin), that of the water above it, or rather of an equivalent column of mercury, and subtracting their sum from the height of the common barometer at the time. All these results were taken from observations made after the apparatus had been so perfectly exhausted of air as to produce the phenomenon just mentioned.

Temperature.	Elasticity.			
	1st Set.	2d Set.	3d Set.	Mean.
	Inches.	Inches.	Inches.	Inches.
52°	0.	0.42	0.40	0.41
62	0.53	0.52	0.52	0.52
72	0.73	0.73	0.73	0.73
82	1.03	1.02	1.02	1.02
92	1.42	1.41	1.42	1.42
102	1.98	1.92	1.95	1.95
112	2.67	2.63	2.66	2.65
122	3.58	3.54	3.58	3.57
132	4.68	4.65	4.72	4.68
142	6.05	6.00	6.14	6.06
152	7.86	7.80	7.89	7.85
162	9.98	9.96	10.04	9.99
172	12.54	12.72	12.67	12.64
182	16.01	15.84	15.88	15.91

"The following formula will be found to give the elasticity belonging to a given temperature, and *vice versa*, with a sufficient degree of accuracy for most purposes, within the range of the experiments, at least, from which they have been formed.

Let t = temperature, e = elasticity, in inches of mercury;

$$T = t + 52, \text{ and } E = e - \frac{1}{10}, m = 94250,000000;$$

Then

$$\frac{T^{5.14}}{m} = E$$

$$\sqrt[5.14]{Em} = T$$

"But as the calculation is most easily performed by logarithms, let L signify the logarithm of the quantity to which it is prefixed:

$$\text{Then } 5.14 LT - 10.97427 = LE$$

$$\frac{LE + 10.97427}{5.14} = LT.$$

"The following table shows the observed elasticities, those derived from calculation by the formula, and the differences of the two, which appear to me to be as small as can be expected, taking a general view.

* In all these experiments Mr Southern was assisted by Mr William Creighton.

Steam.
Mr South-
ern's Ex-
periments.

Tempera- ture.	Observed Elasticities.	Calculated Elasticities.	Differences.
	Inches.	Inches.	Inches.
32o		0.18	
42		0.25	
52		0.35	
62	0.52	0.50	—0.02
72	0.73	0.71	—0.02
82	1.02	1.01	—0.01
92	1.42	1.42	0.00
102	1.95	1.96	+0.01
112	2.65	2.67	+0.02
122	3.57	3.58	+0.01
132	4.68	4.74	+0.06
142	6.06	6.20	+0.14
152	7.85	7.99	+0.14
162	9.99	10.19	+0.20
172	12.64	12.86	+0.22
182	15.91	16.08	+0.17
192	. . .	19.91	. . .
202	. . .	24.45	. . .
212	29.80	29.80	0.00
250.3	59.60	59.69	+0.09
293.4	119.20	118.32	—0.88
343.6	238.40	237.60	—0.80

"I believe it is now generally considered that the temperature 212° is that of water boiling when the barometer is at 30 inches instead of 29.8; and if, in the above algebraic expressions, the following alterations be made, the results from the formulæ will correspond with the adjustment of that point, and fully as well with the experiments generally.

"Let $T=t+51.3$; the index of the power and of the root be 5.13, instead of 5.14; and $m=87344,000000$. So the two last equations will be: $5.13 \text{ LT} - 10.94123 = \text{LE}$; and $\frac{\text{LE} + 10.94123}{5.13} = \text{LT}$.

"The table will stand as follows, supposing the thermometer had been graduated for 212° to correspond with 30 inches of the barometer:—

Temp.	Observed Elasticities.	Calculated Elasticities.	Differences.	Temp.	Observed Elasticities.	Calculated Elasticities.	Differences.
	Inches.	Inches.	Inches.		Inches.	Inches.	Inches.
32	*0.16	0.18	+0.02	142°	6.10	6.22	+0.12
42	*0.23	0.25	+0.02	152	7.90	8.03	+0.13
52	*0.35	0.35	0.00	162	10.05	10.25	+0.20
62	0.52	0.50	—0.02	172	12.72	12.94	+0.22
72	0.73	0.71	—0.01	182	16.01	16.17	+0.16
82	1.02	1.01	—0.01	192	. . .	20.04	. . .
92	1.42	1.42	0.00	202	. . .	24.61	. . .
102	1.96	1.97	+0.01	212	30.00	30.00	
112	2.66	2.68	+0.02	250.3	60.00	60.11	+0.11
122	3.58	3.60	+0.02	293.4	120.00	119.17	—0.3
132	4.71	4.76	+0.05	343.6	240.00	239.28	—0.2

"I remain, with the greatest esteem and respect, Dear Sir, Your very obedient Servant,
"Oakhill, 26th March, 1814."

"JOHN SOUTHERN.

"To JAMES WATT, Esq., Heathfield."

Achard's
Experi-
ments.

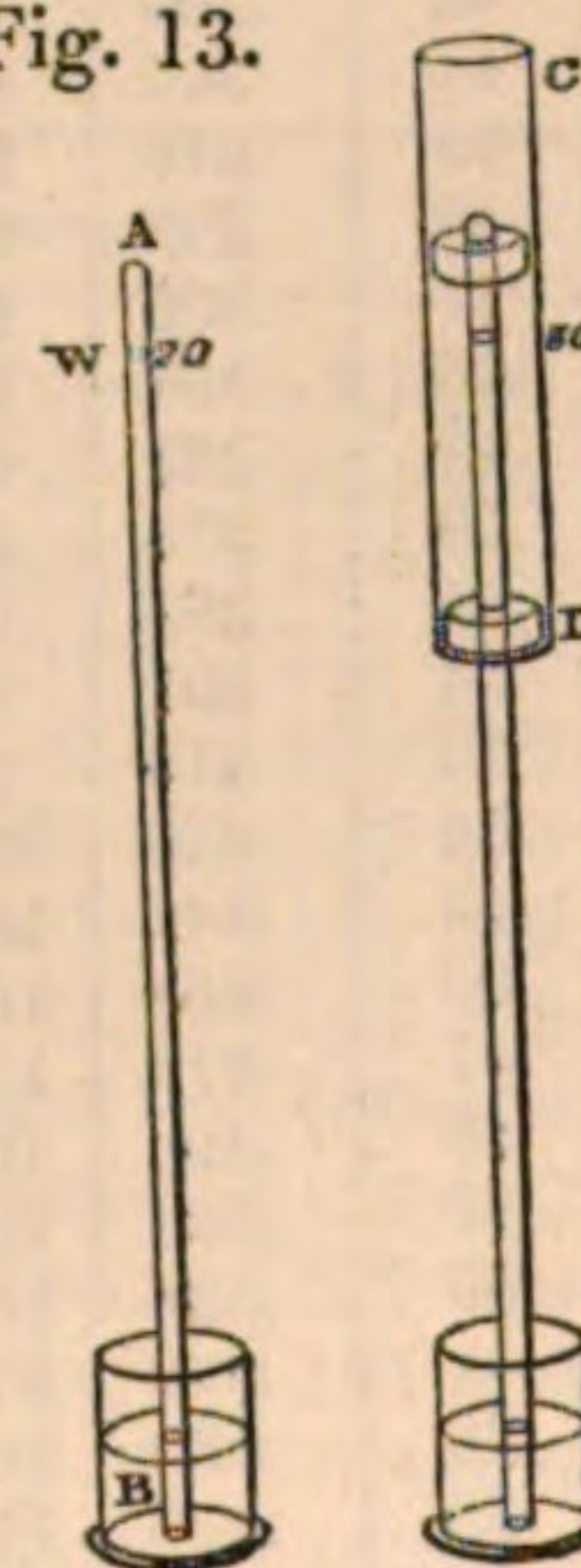
28. In the *Memoirs of the Royal Academy of Berlin* for 1782, there is an account of some experiments made by M. Achard on the elastic force of steam, from the temperature 32° to 212°. They agree extremely well with those mentioned here, rarely differing more than two or three-tenths of an inch. He also examined the elasticity of the vapour produced from alcohol, and when the elasticity was equal to that of the vapour of water, he found that the temperature was about 35° lower. Thus, when the elasticity of both was measured by 28.1 inches

of mercury, the temperature of the watery vapour was 209°, and that of the spirituous vapour was 173°. When the elasticity was 18.5, the temperature of the water was 189.5°, and that of the alcohol 154.6°. When the elasticity was 11.05, the water was 168°, and the alcohol 134.4°. Observing the difference between the temperature of equally elastic vapours of water and alcohol not to be constant, but gradually to diminish, in M. Achard's experiments, along with the elasticity, it became interesting to discover whether, and at what temperature, this difference would vanish altogether. Experiments were accordingly made by the writer of this article, similar to those made with water. They were not made with the same scrupulous care, nor repeated as they deserved, but they furnished rather an unexpected result. The following table will give the reader a distinct notion of them.

Temperature.	Elasticity.	Temperature.	Elasticity.
32°	0.0	140	12.2
40	0.1	160	21.3
60	0.8	180	34.
80	1.8	200	52.4
100	3.9	220	78.5
120	6.9	240	115.

29. Dr Dalton appears to have been the first to escape from the natural enough error of assuming that the vapour of water at 32° would be = 0. His apparatus is the most simple and refined of any that have been employed for temperatures below 212°, and his experiments are those which, to the present day, have the greatest authority. Dr Dalton's first experiments were published in 1793, in his *Meteorological Essays*; afterwards, when more extended, in the *Manchester Memoirs*, 1802; then in the first volume of his *System of Chemistry*, 1808; and finally in the second volume of the same work, 1827. The following is the account given by himself, of his early experiments, in the *Manchester Memoirs*.

"My method is this: I take a barometer tube AB, (Fig. 13.) perfectly dry, and fill it with mercury just boiled, marking the place (30) where it is stationary; then, having graduated the tube, I pour a little water, or any other liquid, the subject of experiment, into it, so as to moisten the whole inside: after this I again pour in mercury, and carefully inverting the tube, exclude all air; the barometer, by standing some time, exhibits a portion of water of $\frac{1}{8}$ or $\frac{1}{10}$ th of an inch, W, on the top of the mercurial column; because, being lighter, it ascends by the side of the tube, which may now be inclined, and the mercury will rise to the top, manifesting a perfect vacuum from air. I next take a cylindrical glass tube CD, open at both ends, of two inches diameter and fourteen inches in length, to each end of which a cork is adapted, perforated in the middle, so as to admit a barometer tube to be put through, and to be held fast by them; the upper cork, C, is fixed two or three inches below the top of the tube, and is one-half cut away, so as to admit water, &c., to pass by, its service being merely to keep the tube steady. Things being thus circumstanced; water of any temperature may be poured into the wide tube, and thus made to surround the upper part or vacuum of the barometer, and the effect of temperature in the production of vapour within can be observed from the depression of the mercurial column at the top. In this way I have had water as high as 155° surrounding the vacuum; but as the higher temperatures might endanger a glass apparatus, instead of it I used the following:—



¹ These are inserted from numerous experiments made by Mr W. Creighton.

Steam.
Dr Dalton's Experiments.

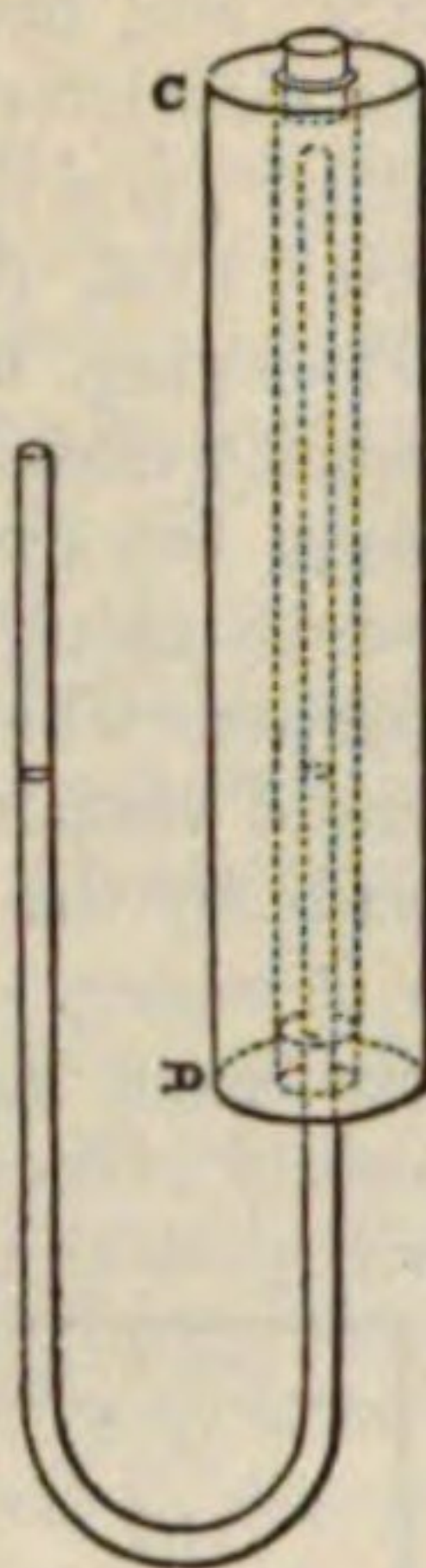
Having procured a tin tube CD, four inches in diameter, and two feet long with a circular plate soldered to one end, having a round hole in the centre, like the tube of a reflecting telescope, I got another smaller tube of the same length soldered into the larger, so as to be in the axis or centre of it; the small tube was open at both ends, and on this construction water could be poured into the large vessel to fill it, while the central tube was exposed to its temperature. Into this central tube I could insert the upper half of a syphon barometer, and fix it by a cork, the top of the narrow tube, also, being corked—thus the effect of any temperature under 212° could be ascertained, the depression of the mercurial column being known by the ascent in the exterior leg of the syphon. The force of vapour from water between 80° and 212° , may also be determined by means of an air-pump, and the result exactly agrees with those determined as above."

"After repeated experiments by all those methods, and a careful comparison of the results, I was enabled to digest the following:—

Table of the Force of Steam from Water in the temperatures from 32° to 212° (1802.)

Temperature.	Force of Vapour in inches of Mercury.	Temperature.	Force of Vapour in inches of Mercury.	Temperature.	Force of Vapour in inches of Mercury.	Temperature.	Force of Vapour in inches of Mercury.
32°	.200	78°	.940	123°	3.59	168°	11.54
33	.207	79	.971	124	3.69	169	11.83
34	.214	80	1.00	125	3.79	170	12.13
35	.221	81	1.04	126	3.89	171	12.43
36	.229	82	1.07	127	4.00	172	12.73
37	.237	83	1.10	128	4.11	173	13.02
38	.245	84	1.14	129	4.22	174	13.32
39	.254	85	1.17	130	4.34	175	13.62
40	.263	86	1.21	131	4.47	176	13.92
41	.273	87	1.24	132	4.60	177	14.22
42	.283	88	1.28	133	4.73	178	14.52
43	.294	89	1.32	134	4.86	179	14.83
44	.305	90	1.36	135	5.00	180	15.15
45	.316	91	1.40	136	5.14	181	15.50
46	.328	92	1.44	137	5.29	182	15.86
47	.339	93	1.48	138	5.44	183	16.23
48	.351	94	1.53	139	5.59	184	16.61
49	.363	95	1.58	140	5.74	185	17.00
50	.375	96	1.63	141	5.90	186	17.40
51	.388	97	1.68	142	6.05	187	17.80
52	.401	98	1.74	143	6.21	188	18.20
53	.415	99	1.80	144	6.37	189	18.60
54	.429	100	1.86	145	6.53	190	19.00
55	.443	101	1.92	146	6.70	191	19.42
56	.458	102	1.98	147	6.87	192	19.86
57	.474	103	2.04	148	7.05	193	20.32
58	.490	104	2.11	149	7.23	194	20.77
59	.507	105	2.18	150	7.42	195	21.22
60	.524	106	2.25	151	7.61	196	21.68
61	.542	107	2.32	152	7.81	197	22.13
62	.560	108	2.39	153	8.01	198	22.69
63	.578	109	2.46	154	8.20	199	23.16
64	.597	110	2.53	155	8.40	200	23.64
65	.616	111	2.60	156	8.60	201	24.12
66	.635	112	2.68	157	8.81	202	24.51
67	.655	113	2.76	158	9.02	203	25.10
68	.676	114	2.84	159	9.24	204	25.61
69	.698	115	2.92	160	9.46	205	26.13
70	.721	116	3.00	161	9.68	206	26.66
71	.745	117	3.08	162	9.91	207	27.20
72	.770	118	3.16	163	10.15	208	27.74
73	.796	119	3.25	164	10.41	209	28.29
74	.823	120	3.33	165	10.68	210	28.84
75	.851	121	3.42	166	10.96	211	29.41
76	.880	122	3.50	167	11.25	212	30.00
77	.910						

Fig. 14.



Dr Dalton afterwards resumed the experimental examination of this subject, and was induced to modify these numbers slightly, as will be seen from our final table.

30. Passing over the experiments of Schmidt, Goldner, Dr Ure's and others, as presenting no important differences from some of these we have already noticed, we come to those of Dr Ure, published in the *Philosophical Transactions* of 1818, and made at Glasgow during 1817. The adjoining figures represent his apparatus.

Fig. 15. represents the construction used for temperatures under and a little above the boiling point. Figs. 16. and 17. are those used for higher temperatures, the last being the more convenient of the two; each was suspended from a lofty window ceiling, and placed in a truly vertical position, by means of a plumb line. Dr Ure gives the following account of his mode of experimenting. "One simple principle pervades the whole train of experiments—which is, that the progressive increase of elastic force developed by heat from the liquid, incumbent on the mercury at L, is measured by the length of column which must be added over L, the primitive level below, in order to restore the quicksilver to its primitive level above, at l. These two stations or points of departure are nicely defined by a ring of fine platina wire, twisted firmly round the tube.

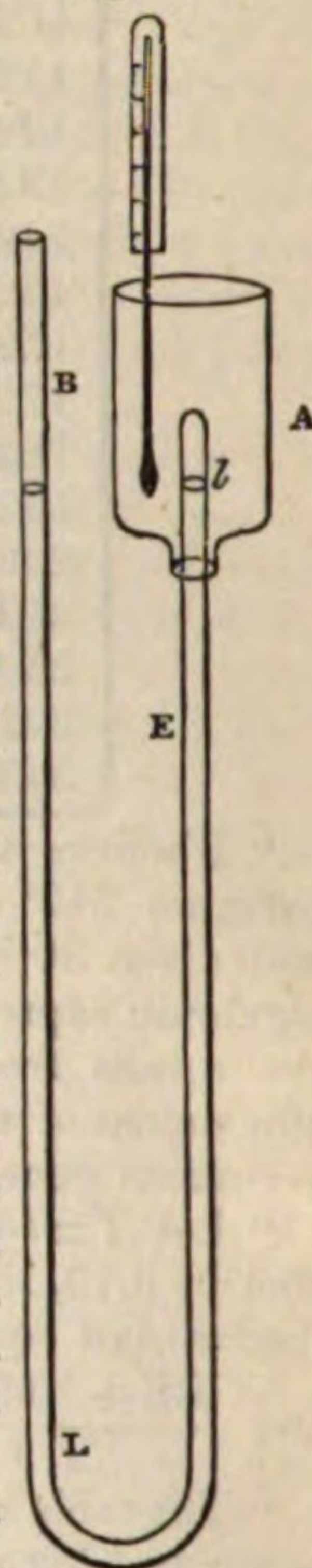
"At the commencement of the experiment, after the liquid, well freed from air, has been let up, the quicksilver is made a tangent to the edge of the upper ring, by cautiously pouring mercury, in a slender stream, into the open leg of the syphon B, the level ring below is then carefully adjusted.

"From the mode of conducting my experiments, there remained always a quantity of liquid in contact with the vapour, a circumstance essential to accuracy in this research.

"Suppose the temperature of the water or the oil in A to be 32° Fahrenheit, as denoted by a delicate thermometer, or by the liquefaction of ice; communicate heat to the cylinder A, by means of two argand flames, playing gently on its shoulder at each side. When the thermometer indicates 42° , modify the flames, or remove them so as to maintain a uniform temperature for a few minutes. A film or line of light will now be perceived between the mercury and the ring at l, as is seen under the vernier of a mountain barometer, when it is raised a few feet off the ground; were the tube at l and L, of equal area, or were the relation of the areas experimentally determined, then the rise of the quicksilver above L would be one-half, or a known submultiple of the total depression, equivalent to the additional elasticity of the vapour at 42° above that at 32° . Since the depressions, however, for 30 or 40° in this part of the scale are exceedingly small, one-half of the quantity can scarcely be ascertained with suitable precision, even after taking the above precautions; and besides, the other sources of error, or at least embarrassment, from the inequalities of the tube, and from the lengthening space occupied by the vapour, as the temperature ascends, render this method of reduction very ineligible.

"By the other plan we avoid all these evils; for whatever additional elasticity be communicated to the vapour above l, it will be faithfully represented and measured by the mercurial column, which we must add over L, in order to overcome it and restore the quicksilver under l, to its zero or initial level, when the platina ring becomes once more a tangent to the mercury. At E, a piece of

Fig. 15.

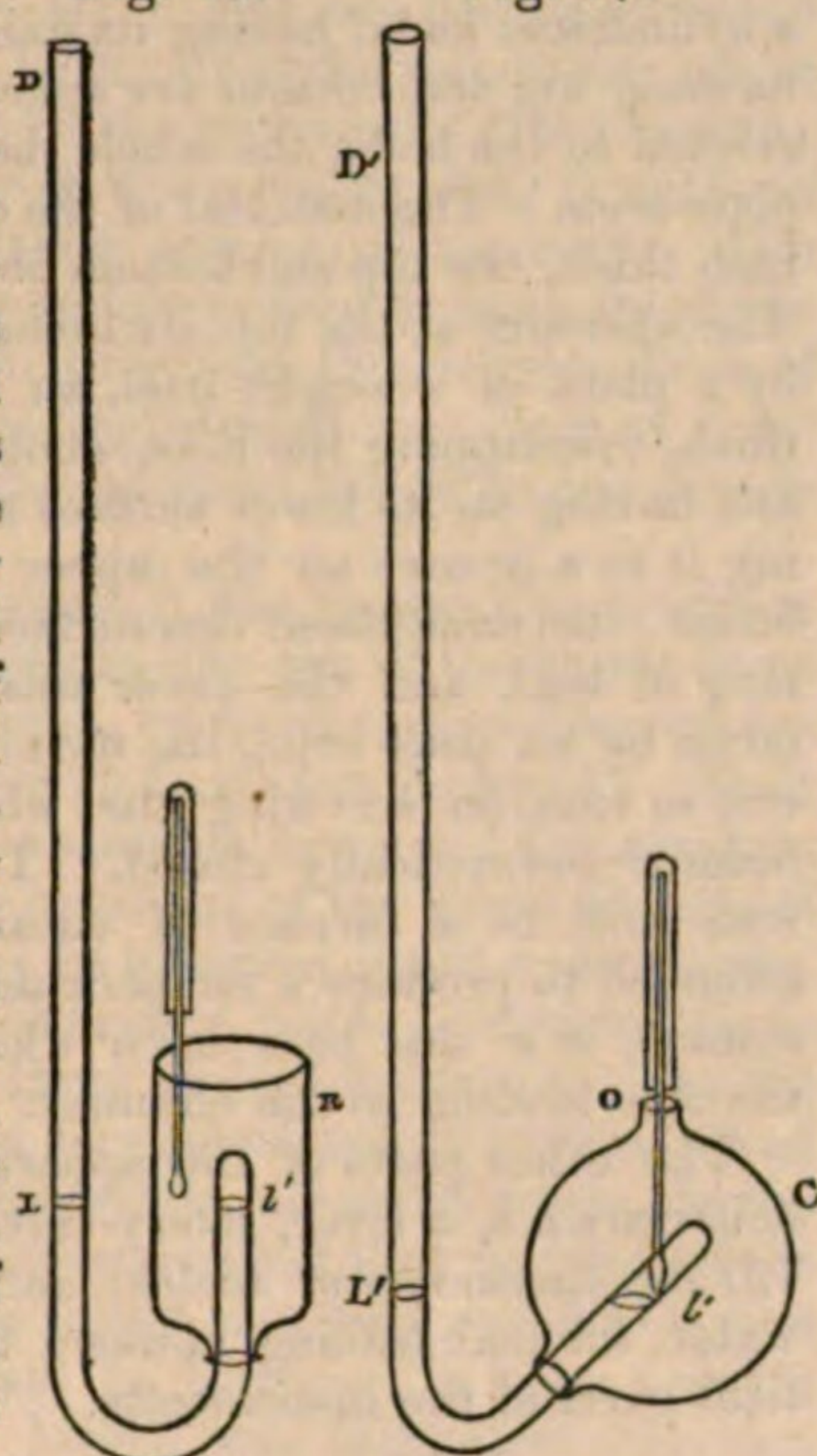


Steam-
Dr Ure's
Experi-
ments.

cork is fixed between the parallel legs of the syphon to sustain it, and to serve as a point by which the whole is steadily suspended. For temperatures above the boiling point, the part of the syphon under E is evidently superfluous, merely containing in its two legs a useless weight of equipoised mercury. Accordingly, for high heats, the apparatus, Figs. 16 or 17, is employed, and the same method of procedure is adopted; the aperture at O, Fig. 17, admits the bulb of the thermometer, which rests as usual on *l'*. The recurved part of the tube is filled with mercury, and then a little liquid is passed through it to the sealed end. Heat is now applied by an argand flame to the bottom of C, which is filled with oil or water, and the temperature is kept steadily at 212° for some minutes. Then a few drops of quicksilver may be required to be added to D', till L and *l'* be in the same horizontal plane. The further conduct of the experiment differs in no respect from what has been already described—the liquid in C is progressively heated, and at each stage mercury is progressively added over L to restore the initial level or volume at *l'*, by equipoising the progressive elasticity. The column above L being measured, represents the succession of elastic forces: when this column is wished to extend very high, the vertical tube requires to be placed for support in the groove of a long wooden prism.

Fig. 16.

Fig. 17.



“The height of the column in some of my experiments being nearly twelve feet, it became necessary to employ a ladder to reach its top. I found it to be convenient, in this case, after observing that the column of vapour had attained its primitive magnitude, to note down the temperature with the altitude of the column, then immediately to pour in a measured quantity of mercury nearly equal to three vertical inches, and to wait till the slow progress of the heating again brought the vapour in equilibrio with this new pressure, which at first had pushed the mercury within the platina ring at *l*. When the lower surface of the mercury was again a tangent to this ring, the temperature and altitude were both instantly observed.

“This mode of conducting the process will account for the experimental temperatures being very often odd and fractional numbers. I present them to the public, as they were recorded on the instant in that particular repetition of the experiment which I consider most entitled to confidence. To trim and fashion the results into an orderly looking series, would have been an easy task; but, in my opinion, this is a species of deception very injurious to the cause of science, and a deviation from the rigid truth of observation, which ought never to be made for any hypothesis: we shall afterwards have ample opportunities of exposing the fallacy of such premature geometrical refinements.

The thermometers were constructed by Creighton with his well-known nicety, and the divisions were read off with a lens, so that $\frac{1}{10}$ th of a degree could be distinguished. After bestowing the utmost pains in repeating the experiments, during a period of nearly two months, I found that the only way of removing the little discrepancies which crept in between contiguous measures, was to adopt the astronomical plan of multiplying observations, and deducing truth from the mean. It is essential to heat with extreme slowness and circumspection the vessels A, B, C. One repetition of the experiment occupies on an average seven hours.

“The apparatus employed in obtaining these results, has

The Elastic Force of the Vapour of Water in inches of Mercury, obtained from Experiments by Dr Ure.

Temp.	Force.	Temp.	Force.	Temp.	Force.	Temp.	Force.	Temp.	Force.	Temp.	Force.
24	0.170	115°	2.820	195°	21.100	242°	53.600	270°	86.300	295.6°	130.400
32	0.200	120	3.300	200	23.600	245	56.340	271.2	88.000	295	129.000
40	0.250	125	3.830	205	25.900	245.8	57.100	273.7	91.200	297.1	133.900
50	0.360	130	4.366	210	28.880	248.5	60.400	275	93.480	298.8	137.400
55	0.416	135	5.070	212	30.000	250	61.900	275.7	94.600	300	139.700
60	0.516	140	5.770	216.6	33.400	251.6	63.500	277.9	97.800	300.6	140.900
65	0.630	145	6.600	220	35.540	254.5	66.700	279.5	101.600	302	144.300
70	0.726	150	7.530	221.6	36.700	255	67.250	280	101.900	303.8	147.700
75	0.860	155	8.500	225	39.110	257.5	69.800	281.8	104.400	305	150.560
80	1.010	160	9.600	226.3	40.100	260	72.300	283.8	107.700	306.8	154.400
85	1.170	165	10.800	230	43.100	260.4	72.800	285.2	112.200	308	157.700
90	1.360	170	12.050	230.5	43.500	262.8	75.900	287.2	114.800	310	161.300
95	1.640	175	13.550	234.5	46.800	264.9	77.900	289	118.200	311.4	164.800
100	1.860	180	15.160	235	47.220	265	78.040	290	120.150	312	167.000
105	2.100	185	16.900	238.5	50.300	267	81.900	292.3	123.100		
110	2.456	190	19.000	240	51.700	269	84.900	294	126.700	312	165.5

the peculiar advantage, over all others, that the mercurial column is never heated. It is the concurrent opinion of all chemical philosophers, that caloric travels downwards in liquids with extreme slowness and difficulty. Indeed, Count Rumford's experiments led him to infer, that heat could not descend in fluids at all.

“It is evident that, in my constructions, figures 15, 16, and 17, only that small portion of quicksilver within the

vessels A, B, and C, will be affected by the heat, but the measuring column is beyond the reach of its influence.”

31. A series of experiments on high-pressure steam was Taylor and subsequently made by Mr Philip Taylor, but he has not described his apparatus. A similar series was also made by Professor Arsberger of Vienna. As their results may be useful for comparison, we have united them in the following table:—

Steam.
Taylor's
and Ars-
berger's
Experi-
ments.

Taylor's and Arsberger's Experiments on High-Pressure Steam.

Temperature	Taylor.	Arsberger.
212°	30.0	"
220	34.9	"
230	41.5	"
232	"	44.4
240	50.0	"
249	"	59.1
250	59.1	"
260	70.1	"
270	82.5	"
274	"	88.9
280	97.7	"
290	114.5	"
293.4	120.4	"
300	133.7	"
320	179.4	"
322	"	176.0
372	"	325.0
432	"	620.0

Experi-
ments of
the French
Academy.

32. We now come to the most imposing series of experiments hitherto conducted. In 1823, the government of France having resolved to legislate on the means for obtaining security in the use of steam-engines, consulted the Academy of Sciences, upon the mode of most effectually promoting the public safety, without placing useless restraints on commercial enterprise and manufacturing industry. The examination into the state of knowledge concerning the phenomena of vapour at elevated temperatures, which resulted from this application, having brought the imperfections of this part of science prominently into notice, the Academy were induced to undertake a long and laborious enquiry, not entirely free from personal danger, into the law connecting temperature with the pressure of steam. The commission consisted of the illustrious members of the Academy, Baron de Prony, Arago, Girard, and Dulong; and the results of their investigation, finished in 1829, are given in the tenth volume of the Memoirs of the Academy of Sciences, printed in 1831. These experiments, conducted principally by the MM. Arago and

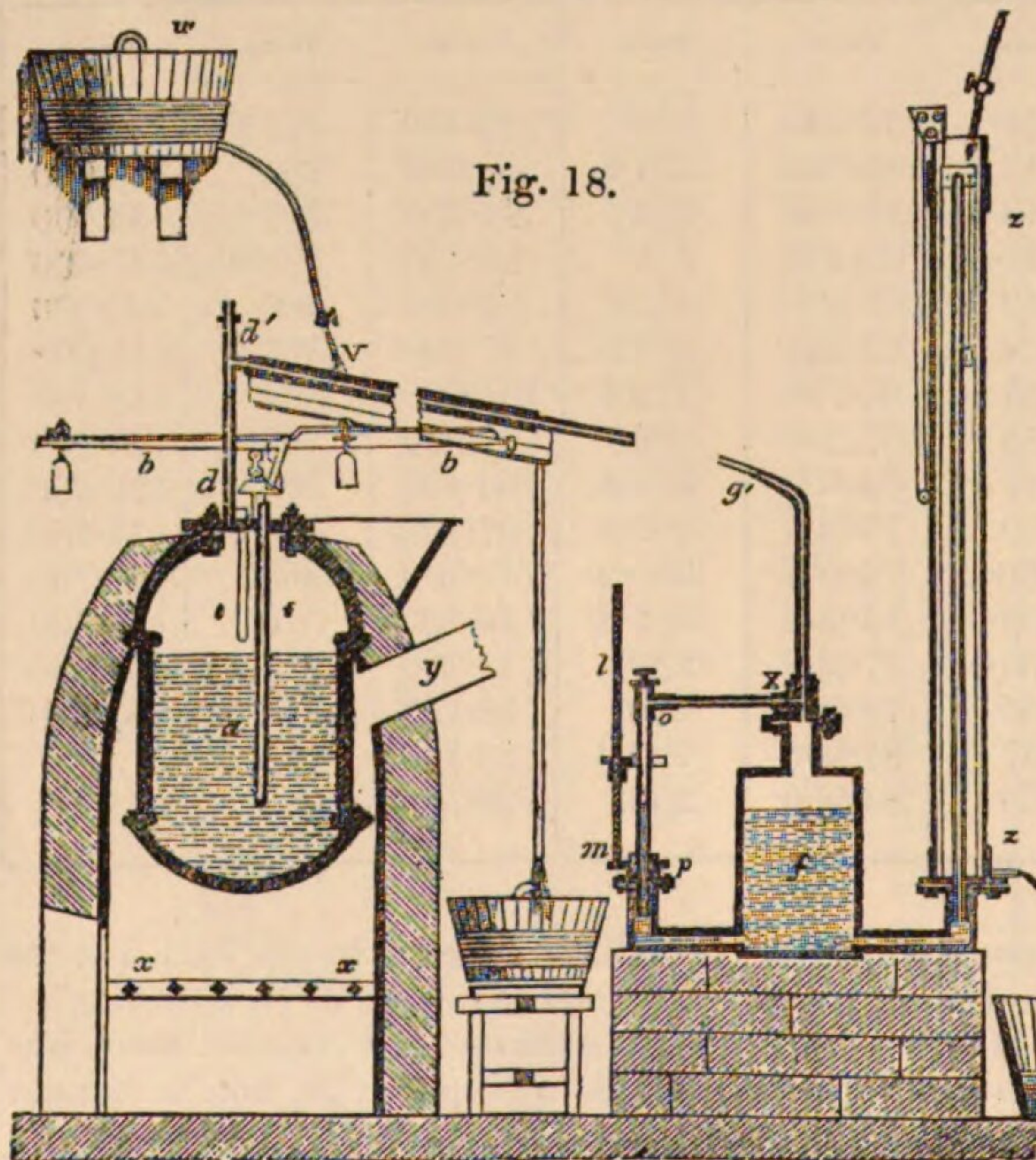


Fig. 18.

Dulong, were on a scale of magnitude and expense suited to the munificence of the French government and the re-

sources of the Academy. The precautions adopted to ensure minute accuracy, entitle them to confidence, no less than the names of two philosophers, so well versed in experiments of a similar nature. They were carried as high as to the twenty-fourth atmosphere of pressure.

The experiments were made in one of the courts of the Observatory. Fig. 18 represents a section of the principal portions of the apparatus. The boiler *a* consists of a cylindrical body, having its axis vertical; the two ends forming top and bottom are spherical segments, strongly riveted to the body, the whole being made of the finest plate iron. The material of the cylindrical part is half an inch thick, the top and bottom being considerably thicker. The aperture at the top, six inches in diameter, was closed by a plate of wrought iron, an inch and three-quarters thick, overlapping the hole, about two inches all round, and having on its lower surface a projecting ring, adapting it to a groove on the upper side of the top of the boiler: between these two surfaces was interposed a thick ring of lead, and the cover was then strongly screwed down by six steel bolts, the nuts of which had head-washers, so that, on screwing the whole together, the cover became hermetically closed. This experimental boiler was built in a furnace of considerable size and mass, intended to produce a temperature of the requisite constancy; *xx* are bars upon which the fire rests; *y* is the flue leading to the chimney.

The other parts of the apparatus connected with the boiler are *b b*, a lever, safety-valve, and weights; *y y* (fig. 19) the thermometer scales; and *w w* reservoirs of cold water, for maintaining uniform temperatures on the vertical parts of the instruments.

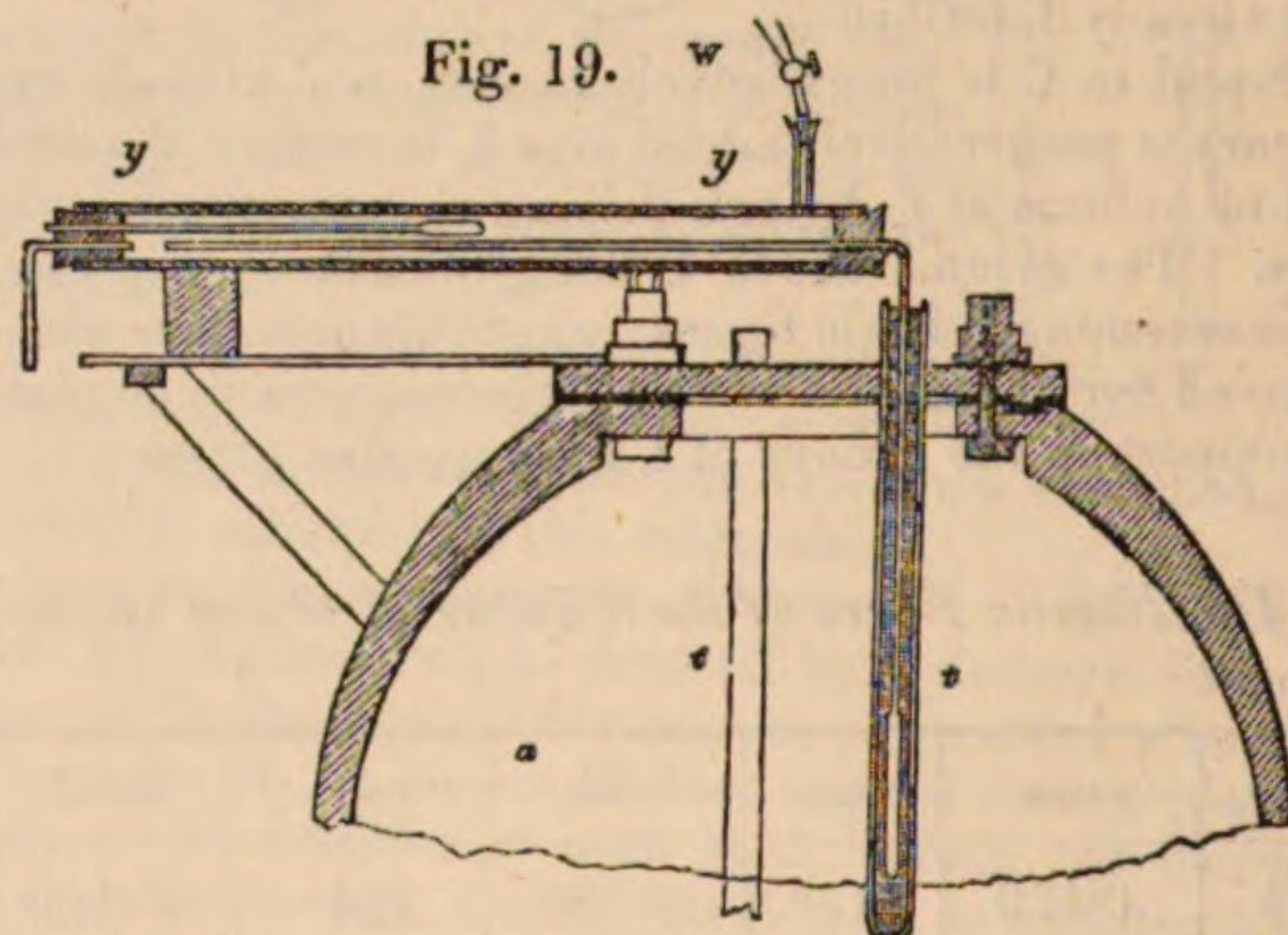


Fig. 19.

During the process of proving the boiler by a hydraulic pump, the common safety-valve, when used as an instrument for measuring with precision the pressure of the fluid in the boiler, was observed to give very erroneous indications, and the necessity of a more delicate apparatus was demonstrated. The improved index of pressure, made use of in the experiments, is shown in fig. 18. For measuring the great pressures to be used, a tube of mercury, 80 feet high, would have been requisite; but there was used, as a substitute for it, a glass tube *z z*, closed at the upper end, filled with dry atmospheric air, and having a length of only five feet seven inches, and an internal diameter of $\frac{1}{2}$ of an inch, and of a thickness nearly equal to its diameter. It was so arranged as to furnish a convenient manometer, capable of giving the same indications, by the contraction of the contained air, as would have been given in similar circumstances, by a column of mercury of the height due to the diminished volume of the air. The graduation of this manometer, however, presented new difficulties.

These difficulties were successfully encountered by the skill and ardour of the academicians. Every one knows that it is impossible to obtain a glass tube of considerable length and magnitude which shall have a tolerably cylindrical interior; and that there are a number of practical

Steam.
Experi-
ments of
the French
Academy.

Steam.
Experi-
ments of
the French
Academy.

difficulties, which render it impossible to obtain even such a tube as that of a common thermometer, which shall possess the uniformity necessary to a good instrument. To make the proper allowance for this inevitable imperfection, the academicians easily might have adopted the same method as that used in the case of thermometer tubes, by determining the volume of successive small portions of its interior; but even this would have furnished a very partial remedy for the evil, because it had not been ascertained that the space occupied by the air in the manometer would diminish in bulk exactly in the proportion of the increase of compressing force, or of the corresponding increase in the height of the equivalent column of mercury. Two problems were therefore to be resolved at once, the elimination of the error of the tube, and the determination of the elasticity of air under high pressures. Both of them were satisfactorily accomplished, by the following laborious research.

As a preliminary measure, it was resolved to graduate the manometer, and determine the law of the elastic force of air under high pressures, by direct comparison with a column of mercury, from 75 to 80 feet in height. Such an experiment required a suitable *locale* and a stupendous apparatus. Among the buildings of the Royal College of Henri Quatre, there may be observed an old square tower, sole relic of the ancient church of Sainte Genevieve: there exist still in the interior three vaulted floors, pierced in the centre, and affording the very supports that were required for the erection of this stupendous mercurial gauge. In the centre of this opening there was raised a squared tree of the required height, and to this it was determined to attach the glass tube of 80 feet in height. To form a single glass tube of so great length was impossible; its own weight, when constructed, under the pressure of the mercury, would have endangered its existence. The glass column was built of separate portions, united in mastic, with great care, in viroles of steel. Each portion of tube was suspended in the air by an exact counterpoise, acting over pulleys fixed to the tree; and the whole of the parts were so united in equilibrio, that each sustained only its own weight, and the pressure of the mercury due to the height of the superior portion of the column. A homogeneous metallic scale was attached, and its divisions read by a vernier, as in the common barometer.

The manometer to be graduated, and this column of mercury, were both connected by tubes with a strong cylindrical vase *f*, holding about 100 lbs. of mercury. When thus placed in communication, a column of water was forced into the vase above the mercury by a hydraulic pump, and the pressure thus produced raised the metal with equal force up into the glass tube column on the one hand, and into the manometric tube on the other. The point to which the air was compressed was read off by a vernier, and the corresponding height of the mercury having been determined, it was manifest that the same degree of compression of the less instrument would ever after serve as the index of an equivalent column of mercury. In this manner the whole tube was graduated by careful experiment. The result of this graduation was satisfactory and very instructive. In forming the scale of the manometer, no room was left for errors of practical execution; and the comparison of the volume of the air with the height of the mercurial column demonstrated the diminution of the volume of the air to be precisely in the ratio of the pressure, so that the law of Mariotte is rigidly correct, even when extended to the extreme case, where the air is reduced to less than $\frac{1}{25}$ part of its usual volume.

This preliminary process having been successfully terminated, the enormous column of glass was now laid aside, and the manometer, with its reservoir of mercury, transported to the court of the Observatory, for the purpose of being attached to the experimental boiler. Figure 18 shows the manometer *in situ*. An iron tube *d d', g'*, com-

posed of gun barrels welded together, connects the cover of the boiler *a*, with the reservoir of the manometer *f*, so as to conduct the pressure of the steam to the surface, which formerly had sustained the mercurial column. The vacant space above the mercury was filled with water, which, by condensation from a stream of water on the outside, was kept full to the constant height *v*. A column of water contained in the glass tube *z z*, and constantly replenished, preserved the column of air, and other parts of the apparatus, at a constant temperature, indicated by a thermometer. A tube *o p*, of glass, communicating with the reservoir of mercury above and below, indicates, on the scale *l, m*, the variation of level arising from the recession of the mercury into the manometer tube.

To ascertain the temperature of the water and steam of the boiler, it had been considered sufficient in the ruder experiments of earlier observers to insert thermometers directly into the boiler itself. Every one who has an acquaintance with these instruments knows, that any difference of pressure on the glass produces a false indication of the instruments, so that even the few inches of mercury in the instrument itself, when inverted, alter its indications, and a slight pressure of the finger would raise it a degree; the inaccuracy of the old method, when used under a pressure of 70 or 80 feet of mercury, or 450 pounds on every inch of the immersed surface of the instrument would have been great. The French academicians avoided this error, by immersing strong iron tubes *t t*, (figs. 18 and 19,) in the water and steam, in which the thermometers, surrounded by liquid metal, were kept in close communication with the heat of the fluids, without exposure to their force. By adopting only very slow variations of temperature, the error arising from the motion of heat was rendered insensible.

The following Table contains the results of Thirty of the most unexceptionable Experiments:—

	1.	2.	3.	4.	5.	
	Smaller Centigrade Thermometer.	Larger Centigrade Thermometer.	Elastic Force, in feet of Mercury at 32 degrees.	In Atmospheres of 76 degrees.	Condition in which the Observations were made.	
1	122.97	123.7	1.62916	2.14	max.	1
2	132.58	132.82	2.1767	2.87	a	2
3	132.64	133.3	2.1816	2.88	p.max.	3
4	137.70	138.3	2.5386	3.348	a	4
5	149.54	149.7	3.4759	4.584	max.	5
6	151.87	151.9	3.6868	4.86	a	6
7	153.64	153.7	3.881	5.12	a	7
8	163.00	163.4	4.9383	6.51	max.	8
9	168.40	168.5	5.6054	7.391	max.	9
10	169.57	169.4	5.7737	7.613	a. s.	10
11	171.88	172.34	6.151	8.114	a	11
12	180.71	180.7	7.5001	9.893	p.max.	12
13	183.70	183.7	8.0352	10.6	a	13
14	186.80	187.1	8.6995	11.48	a. s.	14
15	188.30	188.5	8.840	11.66	max.	15
16	193.70	193.7	9.9989	13.19	a	16
17	198.55	198.5	11.019	14.53	a. s.	17
18	202.00	201.75	11.862	15.65	a	18
19	203.40	204.17	12.2903	16.21	a. s.	19
20	206.17	206.10	12.9872	17.13	a	20
21	206.40	206.8	13.061	17.23	max.	21
22	207.09	207.4	13.1276	17.3	p.max.	22
23	208.45	208.9	13.6843	18.05	a	23
24	209.10	209.13	13.769	18.16	a	24
25	210.47	210.5	14.0634	18.55	p.max.	25
26	215.07	215.3	15.4995	20.44	a	26
27	217.23	217.5	16.1528	21.31	a	27
28	218.3	218.4	16.3816	21.6	p.max.	28
29	220.4	220.8	17.1826	22.66	a	29
30	223.88	224.15	18.1894	23.994	max.	30

Steam.
Experi-
ments of
the French
Academy.

Steam.

A table of temperatures, from 1 to 50 atmospheres, calculated in coincidence with the experiments of the French academicians, and adapted to English measures, is given by us in Article 57, for the purpose of convenient practical reference.

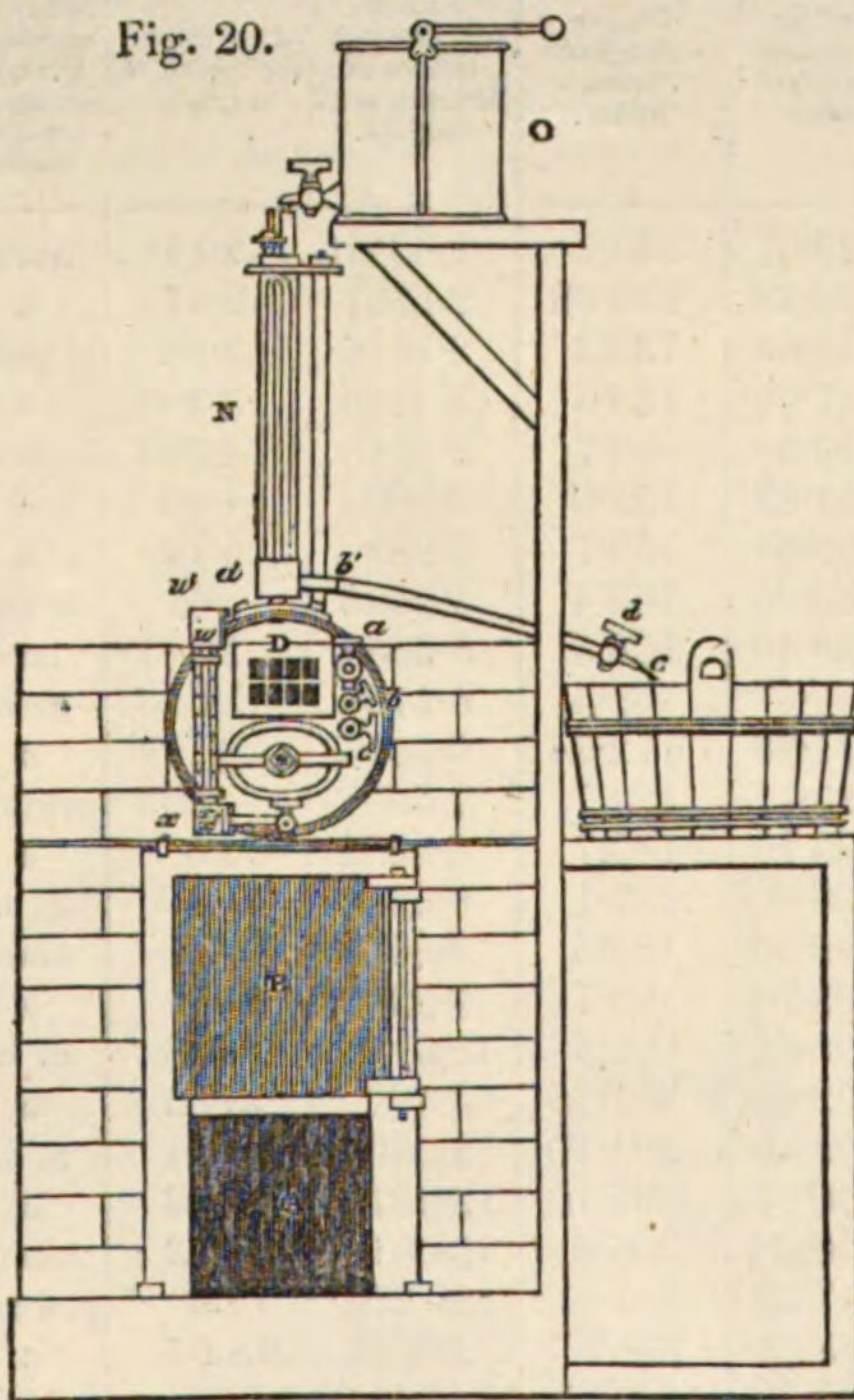
Experiments of the American Committee.

33. The latest series of experiments on the elastic force of high-pressure steam, we owe to America. At the request of the Hon. S. D. Ingham, Secretary of the Treasury of the United States, a committee of the Franklin Institute, of the State of Pennsylvania, was appointed "to examine into the causes of the explosions of the boilers used on board of steam-boats, and to devise the most effectual means of preventing the accidents, or of diminishing the extent of their injurious effects." Among other subjects, such as the strength of boilers, the construction of safety-valves, to which we shall refer in another place, this committee took into consideration the elastic force of high-pressure steam at different temperatures. Funds were placed at their disposal by the House of Representatives, and the committee consisted of such a combination of scientific and practical men, as to give high authority to their results. On the 1st day of November, 1830, the subject was placed in the hands of the following gentlemen:—Professor Alex. Dallas Bache, Mr Benjamin Reeves, Mr W. H. Keating, Mr M. W. Balwin, Mr S. V. Berrick, and Isaiah Sukens.

We shall enter more fully on the description of their apparatus of experiment than we should otherwise have done, because we shall have frequent reference to make to the whole of their experiments, not only in this article, but in our article on the Steam-Engine, where we treat of explosions of boilers and their causes.

The boiler used by the committee is represented in figs. 20, 21, 22. It is a cylinder, twelve inches in internal diameter, two feet ten inches and a quarter in length within, and a quarter of an inch thick, of rolled iron, with the ends rivetted in the usual manner. Fig. 21 is a side view. Figs. 20 and 22 are end views of the boiler,

Fig. 20.



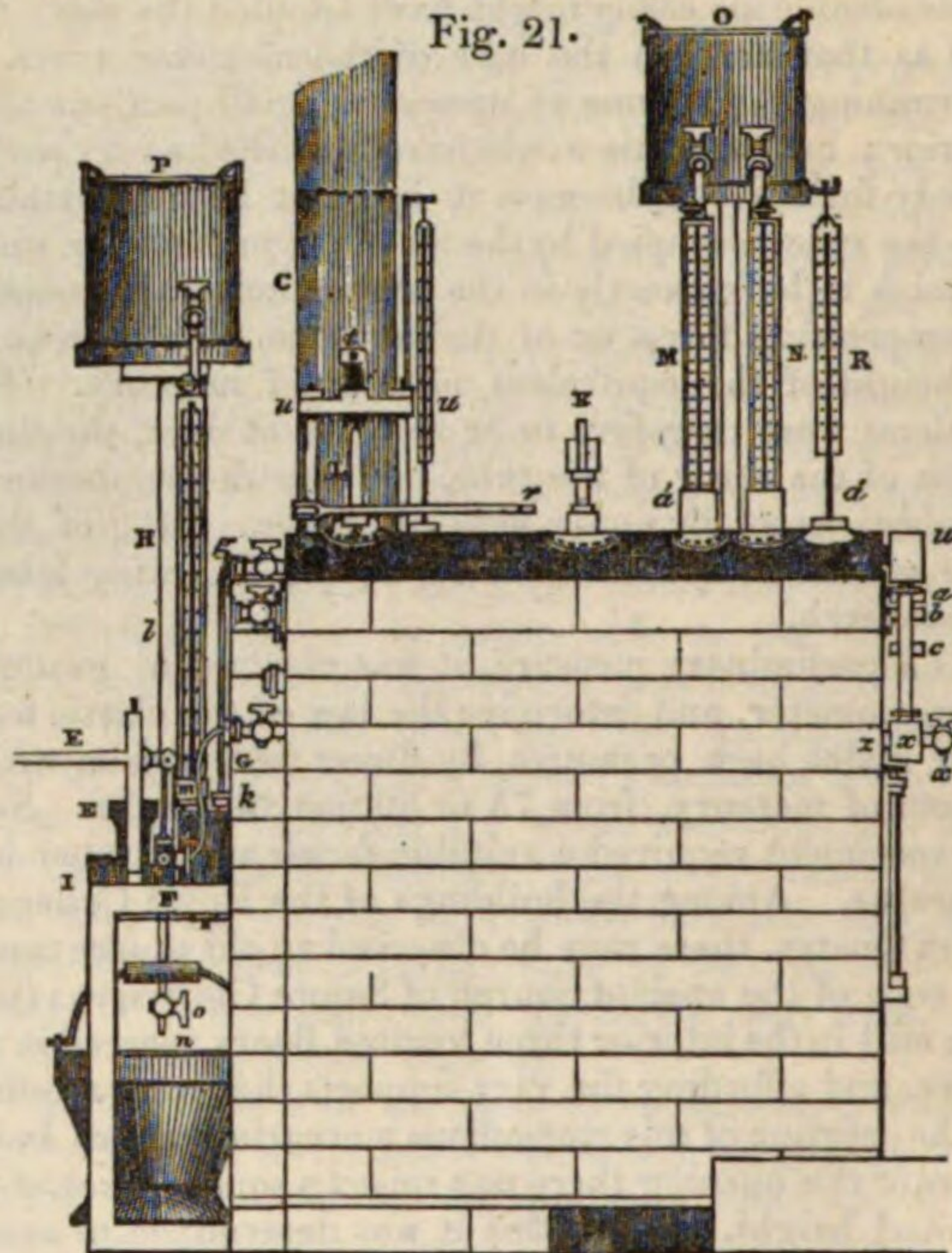
and of the apparatus connected with it. The boiler was placed horizontally in a furnace, the fire surface extending about halfway round the cylinder. The furnace was arranged for a charcoal fire, the grate bars extending the whole length of the boiler, and the fire being applied nearly the whole length. The draught entered by an

opening, closed in the usual manner, and left the furnace through a flue placed at one end and side of the boiler. In fig. 20, A is the ash-pit door, B the furnace door, and in 21 and 22, C is the furnace chimney.

Steam.

Experiments of the American Committee.

Fig. 21.



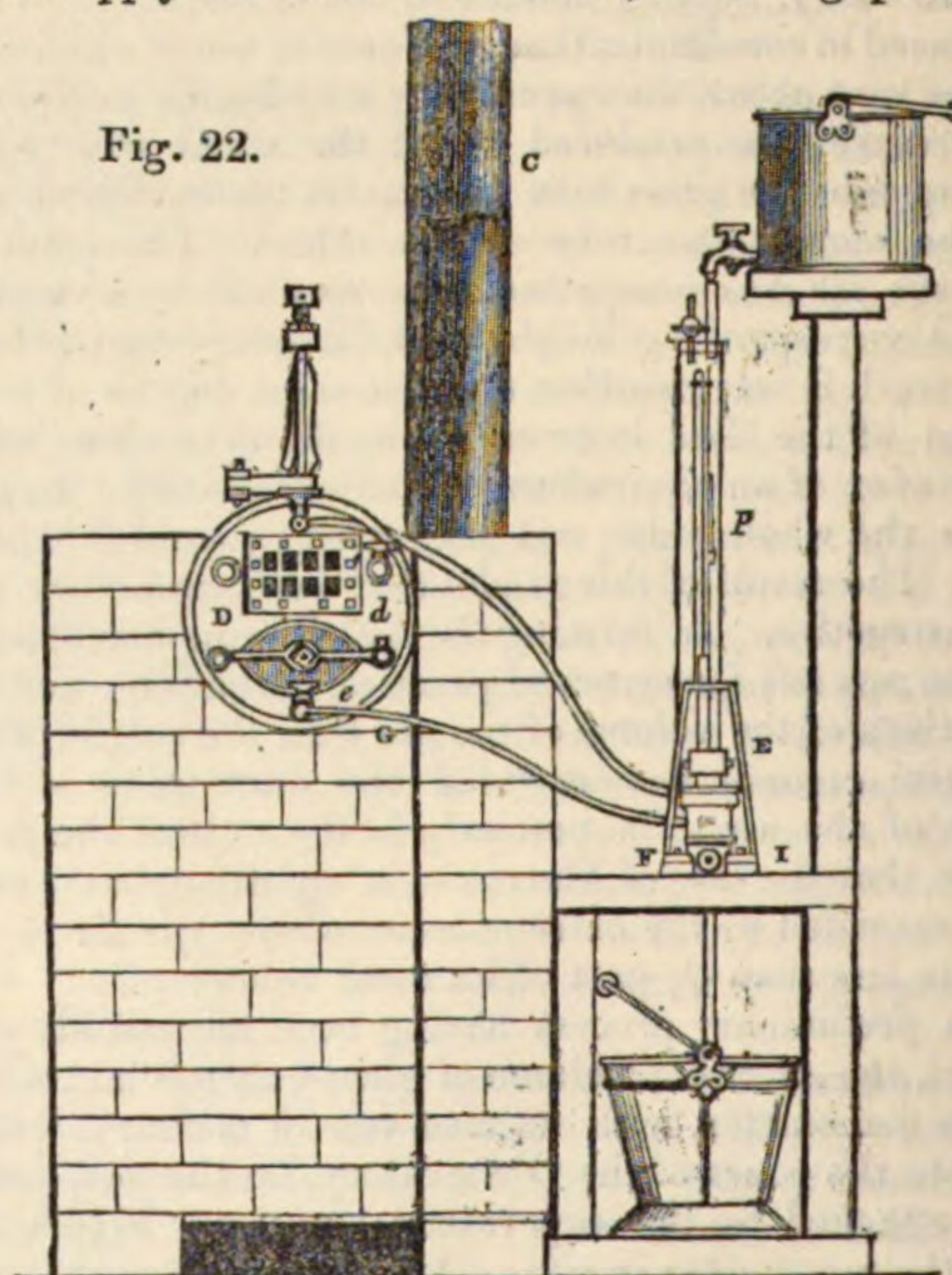
In order to examine, readily, the interior of the boiler during the progress of the experiments, each end was provided with a glass window (D, figs. 20 and 22). The glass used was three-eighths of an inch thick. The openings in the ends, which were rectangular, were two and a half by one and three quarters inches wide.

Three gauge cocks were placed in the front end of the boiler; their positions will be particularly stated hereafter; they are shown in figs. 20 and 21, at a, b, and c.

To the same end and by the side of the gauge cocks, a glass water gauge (w, x, figs. 20 and 21) was attached, a particular description of which will be given in the detail of experiments made to compare its performance with that of the gauge cocks.

To supply the boiler with water, a forcing pump EE'

Fig. 22.



Steam. FG, figs. 21 and 22, was placed near the back end. This pump was of the ordinary construction, with a solid plunger and conical valves; the diameter of the pump was one inch, and the play of the piston one inch and three-quarters. The diameter of the pipe F G, by which the water was conveyed from the pump to the boiler, was three-hundredths of an inch. By a coupling screw, this pipe could be connected with either of the stop cocks *d e*, fig. 22, in the back end of the boiler: the opening of these cocks was two-hundredths of an inch in diameter.

Experiments of the American Committee.

To ascertain the elasticity of the steam within the boiler, a closed steam gauge (H, figs. 21 and 22), was used, a particular description of the construction, &c. of which will be given. This instrument was placed upon the same stand (I, figs. 21 and 22) which supported the pump, so that the same experimenter could observe its indications and attend to the working of the pump. The cistern of the gauge was connected by a flexible pipe *f g*, with the upper part of the boiler.

The safety-valve is shown on the top of the boiler (K, fig. 21), midway between the ends. The graduation of it required much pains, and will receive a separate discussion.

Near the safety-valve is represented (at L, fig. 21,) the fusible plate apparatus, consisting of a sliding plate of iron, moved by a lever. On the other side of the safety-valve are the thermometers (M and N, fig. 21) plunged into iron tubes to give the temperature of the steam and water within the boiler. Above this appears the reservoir O, containing the water intended to maintain the scales of the thermometers at a constant temperature. All these parts require a more detailed description.

Details of the Apparatus.

The steam gauge consisted of a glass tube closed at the upper, and open at the lower end, which passed steam-tight into a reservoir for mercury: when this reservoir was connected with the boiler the pressure of the steam raised the mercury into the gauge tube, compressing the air which the tube contained. The first mercurial gauge which was made, was broken by a sudden access of surcharged steam, in the experiments upon that subject, and was replaced by a second one. The method of graduation, and in general the description of the second gauge, will serve also for the first; the details, only varied slightly.

The glass gauge tube was 26.43 inches in length. To the lower end was connected an iron ferule, terminated above by a projecting ring. This ring was pressed upon the upper end of the pipe *h*, by a coupling screw, which served to form a tight juncture between the gauge and the cistern. The cistern *i* was a cylindrical vessel of cast iron, having the two projecting tubes *h* and *k*, upon which screws were cut: the first of them has been alluded to as giving a passage to the glass tube of the gauge; the second was coupled, by the pipe *f g*, to the boiler.

The gauge tube was not of precisely equal diameter throughout, and it was judged more accurate to graduate small portions of it into equal volumes. This was done by introducing equal measures of air from the point of a sliding-rod gas measure (Hare's); this operation was performed repeatedly, and by multiple measures, to verify the results, until the marks made for the equal volumes, on a paper scale attached to the tube, coincided, in the various trials. The lengths of the spaces occupied by the equal volumes were then carefully measured upon the brass scale to be used with the gauge. The slight differences between the lengths given by adjacent parts of the tube, showed that it might be considered as divided into so many small portions of uniform diameter. The mercury rising into the gauge tube from the cistern when pressure is applied, the level of the cistern is necessarily depressed; the amount of the correction for this depends upon the relation between the areas of the cistern and tube, supposed uniform. The areas of the cistern were found to be, within the limits of its use, sensibly the same;

those of the tube might be so assumed for such a purpose: the ratio was therefore found by filling the gauge tube with mercury, and pouring this into the cistern, noting the rise produced; comparing this with the mean length of the tube, the ratio of depression in the gauge for elevation in the tube was found to be as .01 to 1. The air within the tube was next carefully dried by the introduction of a receptacle of chloride of calcium, of the same length with the tube; the air having been in contact with this substance for a sufficient time, the receptacle was withdrawn through the mercury over which the drying had been effected; the tube was next placed over a dish of mercury, in the receiver of an air-pump, and the air withdrawn, until, on re-admitting air to the receiver, the mercury rose in the tube above the iron ferule.

Steam. Experiments of the American Committee.

The gauge tube was next introduced into the cistern, the level of which, corresponding to the zero of the brass scale was then arranged, and the point of the scale at which the mercury stood was ascertained, the barometer and thermometer being noted.

It was intended in the experiments to keep the pipe from the gauge to the boiler cool, so that it might contain water, and thus give a nearly constant pressure upon the mercury of the cistern, besides preventing the exposure of the apparatus to heat; the height of this column, above the level of the cistern, was therefore ascertained, after the gauge was put in its place by screwing the cistern *i* to the stand.

All the elements for calculating the elasticity of the steam within the boiler, from the height of the mercury of the gauge, were thus known; the temperature of the apparatus being supposed constant.

The elastic force of the steam within the boiler, together with the column of water in the steam-pipe, balances the elasticity of the compressed air within the gauge, together with the column of mercury above the level of that in the cistern. This level is not the original zero, but lower than that, by the depression produced by the rise of mercury in the gauge tube. The depression of the mercury changes the level above which the pressure of the column of water in the steam-pipe is measured, but the change in the pressure, by the column of water, is altogether inconsiderable. The law of the elastic force of dry air, which has been recently shown, by Dulong and Arago, to be accurate, at pressures from one to fifty atmospheres, was made use of in determining the elasticity of the air in the gauge: this elasticity is inversely as the space occupied by the air. From the data already obtained, and upon the principles just stated, a table was calculated, by which the observed heights of the gauge were converted into the corresponding pressures in inches of mercury or in atmospheres. The calculations were rendered rather tedious by the unequal diameter of the bore of the tube, on account of which equal lengths did not correspond to equal volumes. The usual method of calculation was resorted to, namely, to determine, by rigid calculation, the pressures, for points sufficiently near each other, and then to interpolate for intermediate heights.

The foregoing remarks take for granted that the temperature of the air in the gauge, as well as that of the mercury, remains constant; to secure this, an arrangement was adopted similar to that employed by Dulong and Arago for the same purpose. The gauge and scale were surrounded by a glass tube *l*, cemented below into a brass cap *m*, which had an opening in the side, communicating with a discharge pipe *n*, fig. 21. The tube was attached above, by an air-tight juncture, to a tin vessel P, of considerable capacity, compared with the tube. Water being introduced into the glass tube surrounding the gauge, the flow through this tube was regulated by a stop-cock *o*, placed at the end of the discharge pipe, the cistern above being filled with water.

To ascertain the temperature of the column of water

Steam.
Experiments of
the American Com-
mittee.

surrounding the gauge, a thermometer (*p*, fig. 22) with a very small bulb, was attached to the scale at the middle of its height: by this instrument, the flow of water through the casing of the gauge was regulated so as to keep the temperature nearly constant, and any deviations from a constant temperature were ascertained and noted, that the proper correction might be applied. The correction for the expansion of the air in the gauge, by a rise in its temperature during the progress of the experiments, was made according to the rules furnished by the rate of expansion of the gases, as determined by Gay Lussac, extended to compressed air by the experiments of Davy. The correction for the changes of height of the mercurial column, within the range to which the temperature was suffered to increase, could not have been appreciable if acting entirely, and the counteracting effect of the expansion of the glass further justified its being neglected. For similar reasons no reference was made to the effects of heat on the mercury in the cistern *i*, on the cistern itself, and on the water within the pipe communicating with the boiler.

In most of the researches of the committee, refinements in the mode of using the common thermometer would have been out of place. Results which might be obtained with little additional labour, and which would be interesting in both a practical and scientific point of view, were not to be neglected, and to some of them great accuracy was essential. In the questions of the first class, the thermometers were provided with wooden scales, and were graduated by immersion up to the point at which the scale commenced, the scale and upper part of the tube being exposed to the air: this was proper, as they were intended to be immersed in mercury nearly up to the scale. These instruments were examined after coming from the maker's hands, and the instrumental error ascertained. The tubes in which the thermometers were placed, and which contained mercury, were at first placed horizontally in one of the ends of the boiler; this had the advantage of rendering the tube for indicating the temperature of the water entirely independent of the steam, and thus any difference between the temperature of one and the other might be more effectually ascertained, than when the tube giving the temperature of the water passed through the steam. The position of these instruments interfered so much with other parts of the apparatus, and so much inconvenience and danger of error was experienced from the separation of the column of mercury in the thermometer, that these tubes were not used after the first weeks of experiment, and two vertical tubes, placed as already shown, were substituted for them.

The thermometers used, when the relation between the temperature of the steam and water, and the elasticity of the steam were to be observed in conjunction with some of the subjects more directly under the cognizance of the committee, had much pains bestowed upon them.

The scales (*M* and *N*.) were metallic, and surrounded by glass tubes, fitting into a cup *a'*, through the bottom of which the stem of the thermometer passed water tight; a pipe *b' c*, fig. 20, from the side of each cup, and provided with a stop-cock *d*, regulated the flow of water through the enveloping tubes: a tight connexion above with a reservoir (*O*) served, as in the case of the gauge, to supply the tubes with water. Small thermometers on the back of the scale of the large ones, showed the temperature of the water which surrounded them. The enveloping tubes being filled with water at 60°, the position of the boiling point of water and of the fusing point of tin, were used to verify the accuracy of graduation. The latter point, which is high upon the scale of the thermometer, having been very accurately determined, and being easily and with certainty ascertainable, serves as an excellent check upon the graduation. The greatest error within the limits just stated, was in one instrument, three-fourths of a degree, and in the other one degree of Fahrenheit. The scales were graduated from two to two degrees, one quarter of a degree being readily estimated upon them. The corrections required by this examination were made through the medium of a table prepared for the purpose. In order to call the attention to the temperature of the water surrounding the scales, this temperature was recorded from time to time, when the height of the thermometers was observed. At no time did the rise of temperature, permitted in the water, make it necessary to apply a correction for the expansion of the scale. None was required for the cooling effect of the water around the stem upon the mercury, owing to the method of verifying the scale.

The other parts of the apparatus, less general in their use, as the water-gauge, safety-valve, fusible plate apparatus, &c., will be more conveniently described in connexion with the experiments for which they were devised."

34. With this apparatus, and these precautions, a series of experiments were made, the results of which are contained in the following tables:—

The Table, No. 1, contains the temperature observed by the thermometer in the water, corrected for the error of the graduation; the temperature of the scale of the thermometer, with a view to show that it was not allowed to vary too considerably; the observed height of the mercury in the gauge, reduced to its mean height; the temperature

TABLE, No. I.—Of the Elastic Force of Steam at different Temperatures.

Temperature of steam.	Temp. of scale of thermometer.	Height of mercury in air gauge.	Temperature of air in gauge.	Volume of air at observed temperature.	Volume of air at 48° Fahrenheit.	Elasticity of air in inches of mercury.	.01 Height of gauge.	Height + .01 height.	Height + .01 height — 1.29 inches.	Total elasticity in inches of mercury.	Elastic force in atmospheres of 30 inches.
Fah. °	Fah. °	Inches.	Fah. °	Vols.	Vols.	Inches.	Inches.	Inches.	Inches.	Inches.	Atmos.
		3.99*	62	8.33	8.101	27.26	.04	4.03	2.74	30.00	1.00
262 $\frac{1}{4}$	63	15.04	74	3.93	3.737	59.09	.15	15.19	13.90	72.99	2.43
268 $\frac{1}{2}$	71	16.34	"	3.43	3.259	67.76	.16	16.50	15.21	82.97	2.76
275 $\frac{1}{2}$	"	17.34	"	3.05	2.898	76.20	.17	17.51	16.22	92.42	3.08
286 $\frac{1}{2}$	"	18.94	"	2.44	2.319	95.23	.19	19.13	17.84	113.07	3.77
296 $\frac{1}{2}$	"	19.94	"	2.05	1.948	113.36	.20	20.14	18.85	132.21	4.41
298 $\frac{1}{2}$	73	20.11	"	1.99	1.891	116.76	.20	20.31	19.02	135.80	4.53†
302	"	20.44	"	1.86	1.767	124.98	.20	20.64	19.35	144.33	4.81‡
305 $\frac{1}{2}$	76	20.79	75	1.73	1.641	134.57	.21	21.00	19.71	154.28	5.14
313 $\frac{1}{4}$	79	21.39	"	1.50	1.422	155.30	.21	21.60	20.31	175.61	5.85§
317 $\frac{3}{4}$	80	21.64	"	1.405	1.332	165.79	.22	21.86	20.57	186.36	6.21
320 $\frac{3}{4}$	"	21.79	76	1.347	1.275	173.20	.22	22.01	20.72	193.92	6.46
327 $\frac{3}{4}$	"	22.24	"	1.176	1.113	198.41	.22	22.02	20.73	219.14	7.30
333 $\frac{3}{4}$	"	22.69	"	1.004	0.950	232.46	.23	22.92	21.63	254.09	8.47

* This observation shows the height of the gauge before the experiment, corrected for the height of the barometer.

† Mean of four observations

‡ Mean of two observations.

§ Mean of two observations.

Steam.
Experiments of
the American Com-
mittee.

Steam. of the air in the gauge; its volume at the observed temperature; the volume reduced to 48°, the temperature of graduation of the gauge at which the column of mercury, equivalent to an atmosphere, is very nearly 30 inches; the elasticity of the compressed air, in inches of mercury; the correction in the height of the column of mercury, for the depression produced in the cistern below; the height thus corrected: the height, after subtracting the sensibly constant number for the column of water between the level of the steam-pipe from the boiler and the cistern of the gauge; the total elasticity in inches of mercury; the elasticity in atmospheres. The first line of numbers in the table is merely introduced for the convenience of presenting certain data required for subsequent calculation; it gives the height of the mercury in the gauge before beginning the observations, after correcting for the height of the barometer.

Experiments of the American Committee.

A curve traced to represent these observations, the ordinates representing the pressures, and the abscissæ the

temperatures, is quite regular, until the temperature corresponding to eight atmospheres is attained, when it rises abruptly. This fact was explained, by examining the gauge; it was found that the cement used in attaching the glass tube to its ferule had become softened, and had permitted the tube to rise. This defect was remedied and its recurrence prevented. It was then determined to repeat the entire series of observations, and to carry them as high as could be done, with reasonable convenience, aiming particularly, to embrace the range of working pressures of the American engines.

The results are contained in the following table in which the observed data, and calculated numbers, are arranged as in the last table. This table extends to 9.91 atmospheres, and to the temperature of 352° Fahrenheit.

Care was taken that the elasticities were increased not too rapidly, and the last numbers obtained, were verified by keeping the temperature sensibly constant for a considerable time.

Steam. Experiments of the American Committee.

TABLE NO. II.—Of the Elastic Force of Steam at Different Temperatures.

Temperature of Steam.	Temperature of thermometer scale.	Height of mercury in air gauge.	Temperature of air in gauge.	Volume of air at observed temperature.	Volume of air at 48° Fah.	Elasticity of air in inches of mercury.	.01 Height of gauge.	Height + .01 height.	Height + .01 height — 1.29 inches.	Total elasticity in inches of mercury.	Elastic force in atmospheres of 30 inches.
Fah. °	Fah. °	Inches.	Fah. °	Vols.	Vols.	Inches.	Inches.	Inches.	Inches.	Inches.	Atmos.
		5.56*	48	7.695	7.695	25.67	.06	5.84	4.55	30.00	1.00
248 $\frac{1}{4}$	54	14.04	53	4.32	4.277	46.19	.14	14.18	12.89	59.08	1.97
269 $\frac{1}{2}$	—	17.34	52	3.05	3.026	65.29	.17	17.51	16.22	81.51	2.72
284 $\frac{1}{2}$	—	19.64	"	2.17	2.152	91.76	.19	19.83	18.54	110.30	3.68
289 $\frac{1}{2}$	—	20.06	"	1.99	1.974	100.05	.20	20.26	18.97	119.02	3.97
294 $\frac{1}{2}$	—	20.56	53	1.82	1.802	109.63	.21	20.77	19.48	129.11	4.30
299 $\frac{1}{2}$	—	21.04	54	1.63	1.611	122.66	.21	21.25	19.96	142.62	4.75
304 $\frac{1}{2}$	—	21.34	54 $\frac{1}{2}$	1.52	1.500	131.66	.21	21.55	20.26	151.92	5.06
310 $\frac{1}{4}$	—	21.64	"	1.405	1.382	142.94	.22	21.86	20.57	163.51	5.45
314 $\frac{3}{4}$	58	22.04	55	1.25	1.233	160.26	.22	22.26	20.97	181.23	6.04
319 $\frac{3}{4}$	—	22.34	55 $\frac{1}{2}$	1.14	1.124	175.86	.22	22.56	21.27	197.13	6.57
329 $\frac{3}{4}$	—	22.84	56	0.95	0.937	210.84	.23	23.07	21.78	232.62	7.75
334 $\frac{1}{2}$	66	22.94	57	0.92	0.904	218.60	.23	23.17	21.88	240.48	8.02
338 $\frac{1}{4}$	—	23.04	57 $\frac{1}{2}$	0.887	0.870	226.92	.23	23.29	22.00	248.92	8.30
345	—	23.24	"	0.82	0.805	245.44	.23	23.47	32.18	267.62	8.92
348	—	23.34	58	0.787	0.771	256.05	.33	23.57	22.28	278.33	9.28
350	—	23.44	"	0.752	0.737	267.97	.23	23.67	22.38	290.35	9.68
352	—	23.50	"	0.733	0.719	274.92	.23	23.73	22.44	297.36	9.91
346	—	23.28	62	0.807	0.785	251.78	.23	23.51	22.22	274.00	9.13

* This observation shows the corrected height of the gauge before the experiments.

There is one observation, namely, that at 329 $\frac{3}{4}$ °, which is certainly recorded erroneously; but omitting this one, the rest which are given, present a very tolerable regularity in the curve traced to represent them. For the sake of adding to the force of these results, the scattered

observations of temperatures and pressures incidentally made during the other experiments of the committee, are brought together in the annexed table.

A column is added to the table, to show the number of observations employed in obtaining the results.

TABLE NO. III.—Of the Elastic Force of Steam at Different Temperatures.

Temperature of Steam.	Temperature of thermometer scale.	Height of mercury in air gauge.	Temperature of air in gauge.	Volume of air at observed temperature.	Volume of air at 48° Fah.	Elasticity of air in inches of mercury.	+ .01 Height of gauge.	Height of gauge + .01 height.	Height + .01 height — 1.29 inches.	Elasticity of steam in inches of mercury.	Elastic force in atmospheres.	No. of observations.
Fah. °	Fah. °	Inches.	Fah. °	Vols.	Vols.	Inches.	Inches.	Inches.	Inches.	Inches.	Atmos.	
		3.91*	59	8.35	8.169	27.34	.04	3.95	2.66	30.00	1.00	
234	54	8.80	55	6.39	6.301	35.45	.09	8.89	7.60	43.05	1.43	1
239 $\frac{1}{4}$	62	9.94	61	5.94	5.788	38.59	.10	10.04	8.75	47.34	1.58	"
245 $\frac{1}{4}$	68	11.16	63	5.46	5.300	42.14	.11	11.27	9.98	52.12	1.74	5
250 $\frac{1}{4}$	70	12.54	63	4.92	4.776	46.77	.12	12.66	11.37	58.14	1.94	4
256 $\frac{1}{4}$	73	13.88	64	4.38	4.243	52.64	.14	14.02	12.73	65.37	2.18	5
262 $\frac{3}{4}$	77	15.14	64	3.89	3.768	59.27	.15	15.99	14.00	73.27	2.44	2
271	70	16.34	65	3.43	3.316	67.35	.16	16.50	15.21	82.56	2.75	4
278	75	17.44	70	3.01	2.882	77.49	.17	17.61	16.32	93.81	3.13	3
288 $\frac{1}{4}$	75	18.74	68	2.50	2.403	92.94	.19	18.93	17.64	110.58	3.69	3
291	76	19.14	65	2.36	2.282	97.88	.19	19.33	18.04	115.92	3.86	2
292 $\frac{1}{2}$	65	19.44	63	2.25	2.184	102.26	.19	19.63	18.34	120.60	4.02	3
300	73	20.12	65	1.98	1.494	117.33	.20	20.32	19.03	136.36	4.55	4
303 $\frac{1}{2}$	74	20.54	66	1.82	1.756	127.27	.20	20.74	19.45	146.72	4.99	1

* This observation shows the corrected height of the gauge before the experiments.

Steam.
Experiments of
the American
Committee.

This table enables us to go as low as 1.43 atmospheres and is strikingly accordant with the two others as far as they extend in common.

A curve which would be traced by the following table, which may be considered to represent the mean of the foregoing, would differ little more than one-tenth of an atmosphere in any part of the range, from the observations, omitting one noticed in the first, and another noticed in the second table; the pressures in general differing less than one-tenth of an atmosphere from the observed pressures.

Table of the Elastic Force of Steam from One to Ten Atmospheres.

Pres- sure.	Ob- served Temp.	Pres- sure.	Ob- served Temp.	Pres- sure.	Ob- served Temp.	Pres- sure.	Ob- served Temp.	Pres- sure.	Ob- served Temp.
Atmo.	Fah. °	Atmo.	Fah. °	Atmo.	Fah. °	Atmo.	Fah. °	Atmo.	Fah. °
1	212	3	275	5	304½	7	326	9	345
1½	235	3½	284	5½	310	7½	331	9½	349
2	250	4	291½	6	315½	8	336	10	352½
2½	264	4½	298½	6½	321	8½	340½		

To compare our results with those given by the committee of the French Academy, we have traced a curve, from the above table, and another from those of the thirty observations, selected by the committee of the Academy, from their experiments which are below ten atmospheres. The curve of our observations, passes at low pressures nearer to the line AB than that of the French experimenters, and after coinciding at the medium pressures of the table, crosses the latter, differing at 10 atmospheres 5 degrees, or at 352½ degrees .65 of an atmosphere.

The difference here noticed is too considerable to be admitted as within the limits of errors in the apparatus or in observation. Having an authority of so much weight against them, the committee have been driven to examine their results very closely. The care employed in the graduation of the gauge seems to exclude the idea of error from it; the upper portion of the scale was divided to .05 of an inch, and could easily be read to half of that distance, making about .1 of an atmosphere at the highest pressure attained. A specific correction for capillarity was ascertained and employed. In one point of manipulation, namely, the method employed to dry the air, the committee differed from what was usual, and though they think there is reason to confide in that method, they have examined what effect would be produced if air were saturated with moisture. Recent experiments on the passage of gases, out and into vessels placed over mercury, and observations connected with them, warrant, moreover, a suspicion, that dry air standing in a glass vessel over mercury, the surface of which is covered by water, may become impregnated with vapour. The effect of such a source of error they have calculated in the highest and lowest results of table No. II. and find it to be as follows:—

For 248¼° the tension of the vapour is 1.96 instead of 1.97, and 352 „ „ 9.78 „ 9.91. Differing from the numbers given in table No. II. by .01 and .13 of an atmosphere.

This supposition is thus shown to be inadequate to explain the discordance, and must, in fact, be deemed, to a certain extent, gratuitous.

The committee have next compared the results furnished by the safety-valves graduated independently of the gauge, and these, as has already been shown, gave calculated pressures four per cent and ten per cent higher

than the pressures indicated by the gauge. From these independent experimental data we have then an evidence that our results are, probably, not too high.”

Steam.

SECT. III.—ON THE MATHEMATICAL LAW WHICH CONNECTS THE ELASTIC FORCE OF VAPOUR WITH ITS TEMPERATURE.

* 35. An inference which may be drawn from all these experiments is, that Nature seems to affect a certain law in the dilatation of aeriform fluids by heat. They seem to be dilatable nearly in the proportion of their present dilatation. For, if we suppose the vapours to resemble air in having their elasticity in any given temperature proportional to their density, we must suppose that if steam of the elasticity 60, that is, under a pressure of 60 inches of mercury, were subjected to a pressure of 30 inches, it would expand into twice its present bulk. The augmentation of elasticity, therefore, is the measure of the bulk into which it would expand, in order to acquire its former elasticity. Taking the increase of elasticity, as a measure of the bulk into which it would expand under one constant pressure, we see that equal increments of temperature produce nearly equal multiplications of bulk. Thus, if a certain diminution of temperature, diminishes the bulk of steam ¼, another equal diminution will very nearly diminish this new bulk ¼. Thus, in our experiments (Art. 25), the temperatures being in arithmetical progression, having equal differences, we see that the corresponding elasticities are very nearly in the continued proportion of 1 to 2, thus:

Temperatures	110°	140°	170°	200°	230°
Corresponding Elasticities,	2.25	5.15	11.05	22.62	44.7.

Now, although extreme temperatures differ considerably from this law, still we see that there is a considerable approximation to it; and it will frequently assist us, to recollect that within these limits an increase of 30° of temperature nearly doubles the elasticity and bulk of watery vapour.

This law obtains exactly in air and other gases, all of which are subject to the Boylean law, or law of Marriotte, as it is called, and have their elasticity proportional to their bulk inversely. If the bulk were always augmented in the same proportion by equal augmentations of temperature, the elasticities would be accurately represented by the ordinates of a logarithmic curve, of which the temperatures are the corresponding abscissæ; and we might contrive such a scale for our thermometer, that the temperatures would be the common logarithms of the elasticities, or of the bulks having equal elasticity; or, with our present scale, we may find such a multiplier m , for the number t degrees of our thermometer (above the temperature where the elasticity is equal to unity), that this multiple shall be the common logarithm of the elasticity F ; so that

$$\text{Log. } F = m t \dots\dots\dots A.$$

36. As Dr Dalton was one of the earliest to investigate the properties of steam by well-contrived experiment, he has likewise been the most successful in obtaining profound and accurate views of those general relations which connect this with co-ordinate branches of physical knowledge. His experimental researches have been the model of imitation to all subsequent investigators. His apparatus was simple, his artifices were highly refined, and his processes elegant and precise; and, consequently, the results of his labour were immediately transferred to the works of highest philosophical character on the Continent and at home, and became part of the staple of accurate science. But his philosophical views were not so readily and widely received, and the fault lay, in part, with their author himself. He had overreached the ex-

Dr Dalton's Investigation.

Steam.
Dr Dalton's In-
vestigation.

isting condition of the other branches of contemporaneous science; and in taking for granted the accuracy of the existing state of knowledge, he proceeded to raise a theoretical structure on ground not yet sufficiently ascertained and determined. The result has been, as might have been anticipated, that now, when the progress of accurate knowledge has altered the conditions on which his system was based, his theory, becoming inapplicable to the facts, has been thrown aside, and, instead of having been modified, as it ought to have been, in conformity with the advancement of science, it has been hastily abandoned or undeservedly neglected.

From an extensive and laborious review of all that has since been added to the stores of our experimental facts on the properties of vapour, we have been conducted to this conclusion, that of all the views that have been taken of the constitution and laws of vapour, Dr Dalton's are those from which we may gain the clearest and most adequate conceptions; and therefore we have undertaken the task of reviewing the subject, and of making those changes and modifications which are now required to represent with fidelity and precision the advanced state of our knowledge.

If we examine any series of even the earlier experiments on the vapour of water (such as those in Art. 27), we cannot fail to recognise a certain degree of regularity in the progress of the increasing force of the vapour as the temperature is successively augmented. At the temperature of freezing water, the force of its vapour being taken at two-tenths of an inch, we see that it becomes more than *doubled* by raising the temperature $22\frac{1}{2}^{\circ}$: this again is rather more than *doubled* at $22\frac{1}{2}^{\circ}$ of additional heat; and this is again exactly *doubled* by a third addition of $22\frac{1}{2}^{\circ}$. But another addition of $22\frac{1}{2}^{\circ}$ of heat scarcely doubles the pressure; and $22\frac{1}{2}^{\circ}$ more fall still further short of producing that effect; so that, while the increase of the force of the steam takes place rapidly, with equal additions of heat, the rapidity of the increase does not maintain a constant proportion, but slowly diminishes as the temperature ascends. This will be plainer in the following table:—

Temperature of the Vapour.	Pressure on Mercury.	Proportion of Increase.	Decrease of Proportion.
32°	0.200	$2 + \frac{17}{100}$	8.
54½	0.445		8.
77	0.910		9.
99½	1.820	$2 + \frac{0}{100}$	8.
122	3.500	$2 - \frac{10}{100}$	8.
144½	6.450	$2 - \frac{16}{100}$	9.
167	11.250	$2 - \frac{25}{100}$	8.
189½	18.800	$2 - \frac{23}{100}$	8.
212	30.000	$2 - \frac{41}{100}$	8.

From this simple collocation of results, a principle of progression is manifested. The number of degrees in the first column increases at each step by $22\frac{1}{2}$ degrees, and the number in the second column on the same line is nearly doubled every step. At first, as the third column shows, it is more than doubled by $\frac{17}{100}$, next time it is more than doubled by $\frac{0}{100}$, and next it is doubled exactly; after this, however, it falls $\frac{10}{100}$ short of being doubled, next time by twice that quantity, and so on, till we find at last that it falls short of doubling every time by about 8 or 9 hundredths for every $11\frac{1}{2}$ degrees. Although, therefore, we may at first be disappointed in finding that the reduplication does not proceed with the regularity of a law of nature, still it is satisfactory to know that the deviation from this progression is itself the subject of a tolerably simple law, so as to enable us to predict, with some measure of

VOL. XX.

accuracy, what would take place if we were to add another increment of $22\frac{1}{2}$ degrees. We should then diminish the number in the third column by $\frac{9}{100}$, and by doubling the preceding numbers, $2 - \frac{41}{100}$ we should have at

$$234\frac{1}{2}^{\circ} \quad 45.00 \quad 2 - \frac{50}{100} \quad -9$$

And again at

$$257 \quad 63.90 \quad 2 - \frac{58}{100} \quad -8$$

It was in this way that Dr Dalton examined his experiments, and proceeded to form his tables, so as to include not only those points which he had already examined by experiment, but to fill up the vacancies, and extend them beyond the range which his actual observation had reached. He thus completed the table which we have already given. This was much more accurate than any previous table, and, being more extensive, formed a valuable addition to our knowledge.

This simple method of interpolation by which Dr Dalton constructed his table, although it suited perfectly, the limited object which he at that time had in view, and coincided with the limited range of his observations, was not of a sufficiently general description to stretch far beyond that sphere. It is obvious, that if his progression were continued much further, it would come to an end of itself; because the constant diminution of the proportion in the third column would bring it down to nothing, and so the march of the method would close and retrograde, and would thus bring the method of the formation into opposition with the march of the fact, for the force of the vapour continues to increase. Dr Dalton was himself the first to recognise the limited applicability of his method of interpolation to wide ranges of temperature; and, accordingly, in his lectures on heat, delivered at Edinburgh and Glasgow in 1807, and in his *New System of Chemistry*, published 1808, he developed those larger and more matured views which had grown up in his mind during a longer and more thorough investigation of the subject.

It does not belong to this article to consider the nature, and decide on the merits of Dr Dalton's theory of temperature; nor is a perfect acquaintance with that theory of any further use in understanding his views of the constitution of vapour, than to enable us to perceive how he was led from the former to the latter. For the validity of his views regarding steam, it is indeed of no consequence whether the theory of temperature from which it was originally deduced, be true or erroneous. The general laws which he has determined for elastic vapours, form the well-settled foundation on which any theory of temperature, true or false, must in some measure ultimately rest.

The only circumstances in regard to temperature which it is proper to keep in view, are these: that the present thermometer used to indicate temperature is not to be regarded as an exact measure of the *quantity* of heat producing that temperature. This is shown from the circumstance, that the same quantity of fuel which heats water 10° from 180° to 190° , will not heat it from 80° to 90° , an equal interval. From considerations of this nature it was evident that the divisions of the common scale were too large near the bottom, and too small in the higher portions; and Dr Dalton evinced this difference to be so great, that 72° of the common scale below the freezing point of water down to the freezing point of mercury, were to be reckoned as equivalent to as many as 207° of Dalton's scale. Proceeding on this view, it was necessary to find the ratio of these two series of indications, the indications of Dalton's and of Fahrenheit's scale; and he accordingly found that the progression of Fahrenheit's scale was in a high geometrical proportion to the increments of true temperature of the new one. On this principle he proceeded to construct his new scale of temperature—of which the following is a specimen.

4 F

Steam.
Dr Dalton's In-
vestigation.

Steam.	Fahrenheit's Scale.	Dalton's Scale.
Dr Dalton's Investigation.	—40° (Freezing point of Mercury),.....	—175°
	32 (Freezing point of water),.....	+ 32
	110 (Middle of scale),.....	122
	212 (Boiling point of water),.....	212
	296	272
	342.7	302
	409.8	342
	520.3	402
	600.7	422

By this new scale of temperature it was found that many of the apparent anomalies in the effects of heat were resolved, and the complex relations of its phenomena rendered very simple. Amongst others, the most important were the phenomena of vapours, as it was found that, on the new scale of temperature, the elastic force of different vapours increased almost exactly in a uniform ratio to equal increments of heat.

But the further progress of experimental science soon raised up serious grounds of objection to this view. It was found that Dr Dalton had rated the inaccuracies of the present scale somewhat too high. His results were thus rendered inapplicable to the advanced state of some branches of thermal science; and his theory, instead of being modified and improved, was first hastily discredited and then summarily dismissed. Unable to follow the theory to its whole extent, it was abandoned even when it had furnished a safe guide thoroughly to explicate the intricacies of obscure truth.

It is now, therefore, necessary to examine the views of those who have endeavoured to form adequate representations of the mathematical law which connects the elastic force of vapour with its temperature. We shall first of all examine the methods and views which they have adopted, and then consider whether there may not be deduced from the clear theoretical views of Dr Dalton, tested and modified by the results of modern experiment, mathematical expressions of a character, at once less empirical, and more closely in accordance with observed phenomena.

M. de Prony's Formulae.

37. M. de Prony was the first to represent, by a purely empirical formula, the law which governs the relation between the temperature and the elasticity of aqueous vapour. It was derived by him, in 1796, from the experiments of M. de Betancourt, and constructed according to a method of interpolation, which he afterwards presented to the Academy of Sciences, and which they have placed among the *Mémoires des Savans Etrangers*.

The Formula which he has thus obtained is

$$y = e^{\mu + \lambda x} - e^{\mu' + \lambda' x} - e^{\sigma x - \rho} + e^{\sigma' x - \rho'};$$

y being the height of the mercurial column of pressure.
 x the temperature.

e the base of the common log.	= 10.
μ an empirical co-efficient,	= 0.068831
λ	= 0.019438
λ'	= 0.013490
σ	= 0.058576
σ'	= 0.049157
ρ	= 4.686080
ρ'	= 3.932560

The same formula holds in the case of alcoholic vapour, the numerical co-efficients being changed, and a constant quantity $A=1.126447$ subtracted from the result.

$$\mu = -0.04853, \lambda = 0.02393, \sigma = 0.0467, \rho = 2.60249$$

$$\mu' = -0.63414, \lambda' = 0.09653, \sigma' = 0.0294, \rho' = 1.64909$$

This formula was afterwards improved by its author, and presented in the following more elegant and convenient shape.

$$z = \mu \rho^x + \mu' \rho'^x + \mu'' \rho''^x + \mu''' \rho'''^x \dots \dots \dots B.$$

Where z is the mercurial column of pressure, x the tem-

perature centigrade, and $\mu, \mu', \mu'', \mu''', \rho, \rho', \rho'', \rho'''$ equidistant constants derived from experiment.—For water, these values are:—

$$\mu = -0.0000000196 \quad \rho = 1.136006$$

$$\mu' = +0.023403 \quad \rho' = 1.038037$$

$$\mu'' = -0.023403 \quad \rho'' = 1.022490$$

and hence he has formed the numbers which we have united in a subsequent table.

M. de Prony's formula for the vapour of alcohol is—

$$z = \mu \rho^x + \mu' \rho'^x + \mu'' \rho''^x + \mu''' \rho'''^x;$$

the constants being

$$\mu = -0.000058 \quad \rho = 1.090391$$

$$\mu' = +0.024669 \quad \rho' = 1.045453$$

$$\mu'' = +0.005677 \quad \rho'' = 0.836030$$

$$\mu''' = -(\mu + \mu' + \mu'') \\ = -0.030288$$

These numbers refer to the centigrade thermometer, and to an atmosphere of 0.7577 metres in height.

These formulæ indicate some singular phenomena at high temperatures, which have not been observed in recent experiments, and may therefore be deemed anomalies of the formulæ themselves rather than the legitimate results of the experiments they were intended to represent. The formulæ are, besides, much too operose to be useful.

38. The experiments of Dr Dalton are adopted by Laplace's place in the fourth volume of the *Mécanique Céleste*, Formula. where we find him applying them to the calculation of the influence of the aqueous vapour of the atmosphere upon astronomical refractions. As an empirical formula agreeing sufficiently with Dr Dalton's experiments, he adopted the following approximation:—

$$f_n = p. (10)^{n \cdot 0.0154547 - n^2 \cdot 0.0000625826} \dots \dots \dots C.$$

f being the force at any temperature n of the centesimal scale, reckoned from the point of ebullition, and p the pressure of the atmosphere = 0.76 metres; or that we have only to add to the log. of 0.76 the quantity $n \cdot 0.0154547 - n^2 \cdot 0.0000625826$ and we have the log. of the common tabular logarithm of the corresponding elasticity at n centesimal degrees of temperature.—*Méch. Cel.* iv. 273.

These numbers agree very well with the observations they were intended to represent, from 0° to 100° centigrade, but are found inaccurate above and below these points.

39. M. Biot, adopting still the methods and experiments of Dr Dalton, found it necessary to modify the formula in order to obtain a closer approximation to truth. Using the notation in which we have expressed Dr Dalton's method of calculation, Biot considers

$$f_n = p. a_n$$

as a first approximation; of which the logarithmic form is

$$\text{Log. } f = \text{log. } 30. + n \text{ log. } a;$$

which would always give the logarithm of the elastic force, provided the ratio were accurately constant; but, as it is variable in Dr Dalton's observed numbers, it would be convenient to represent the variation of the logarithm of the elastic force thus:—

$$\text{Log. } f_n = \text{log. } 30. + \alpha n + \beta n^2 + \gamma n^3, \&c.$$

α, β, γ , being constants derived from experiments thus—and setting out from 100° cent. as the zero—

$$\text{If } n = 0^\circ \text{ the number given by exp. is } F_0 = 30. \text{ in.}$$

$$n = 25 \dots \dots \dots F_{25} = 11.250$$

$$n = 50 \dots \dots \dots F_{50} = 3.500$$

$$n = 75 \dots \dots \dots F_{75} = 0.910$$

By substituting successively these values in the formula we get

Steam. — 0.4259687 = 25 α + 625 β + 15625 γ .
 Biot's — 0.9330519 = 50 α + 2500 β + 125000 γ .
 Formula. — 10.5180799 = 75 α + 5625 β + 421875 γ .
 From these three equations we can readily obtain the three values wanted of α , β , and γ , and which we find to be

$$\begin{aligned}\alpha &= -0.01537419550 \\ \beta &= -0.00006742735 \\ \gamma &= +0.00000003381\end{aligned}$$

and hence the whole equation

Log. 30. $f_n = \log. 30. + \alpha n + \beta n^2 + \gamma n^3$
 is now determined in English inches for the centigrade thermometer; and in order to compare it with the French observations, it is only necessary to remember that 30. in. = 0.7679 French metres, and to transform it thus:
 Log. $F_N = \log. 0.76199 - 0.00112919957 - 0.01537278757 \dots N$
 — 0.00006731995 N^2 + 0.00000003374 N^3

and in the common table of logarithms

$$F_N = 0.76.10 \text{ AN} + \text{BN}^2 + \text{CN}^3$$

or,

Log. $F_N = 7.8808201 + \text{AN} + \text{BN}^2 + \text{CN}^3$
 which are almost identical with Laplace's formula (C), the degrees being reckoned positively from 100° cent. downwards, and negatively upwards.

In degrees Fahrenheit and English inches, the formula in this shape becomes—

$$\text{Log. } F_f = 1.47712137 + 0.00854121972f - 0.00002081091f^2 + 0.00000000580f^3 \dots D.$$

These formulæ are far from representing the results of late experiments at high temperatures, although, within the limits of one atmosphere, they accord pretty closely with Dr Dalton's early observations.

Ivory's Formula. 40. In the first volume of the new series of the *Philosophical Magazine*, Mr Ivory has given a formula constructed to represent empirically the experiments of Dr Ure. It is—

$$\text{Log. } \frac{e}{30} = .0087466t - 0.00015178t^2 + 0.00000024825t^3 \text{ E.}$$

The application of this formula is laborious. It is of exactly the same nature with that of Laplace and Biot, and only represents the observations of Dr Ure within their narrow limits; extended to higher temperatures, it seems to deviate considerably from the truth, as may be seen from our table (Art. 57.)

Schmidt's and Soldner's Formula. 41. Schmidt and Soldner, reviewing Dr Dalton's experiments, have each constructed a formula to represent them:

$$\text{Schmidt's is—} F = t^{1.363} + .0021t \dots F.$$

Soldner's formula is—

$$F = \text{Log. } 30.13 - \frac{(662-t)(212-t)}{52042} \dots G.$$

Mr Tregaskis's Theorem. 42. In the *Edinburgh Journal of Science* for 1829, Mr Tregaskis has given a theorem, which furnishes a rough approximation to experiment. It is this: that $\frac{1}{2}$ of the temperature above 32°, added to vapour, will double its elasticity.

M. Roche's Formula. 43. M. Roche, Professor of Mathematics at Toulon, sent to the Academy of Sciences, in 1828, a memoir on this subject, in which he proposes a formula, deduced from general principles. This formula is—

$$F = 760 + 10 \frac{mt}{11 + 0.03t} \dots H.$$

This formula agrees closely with the French experiments.

Dr Young's Formula. 44. Dr Thomas Young invented a species of formula entirely new. Abandoning altogether the formula in which one of the variables is involved as an exponent, and abandoning altogether the views from which formulæ of this kind had been derived, he assumed an expression which is apparently perfectly arbitrary, and which has been adapted empirically to the experiments of Dr Dalton. It is this:

$$F = (1 + 0.0029t)^7 \dots I.$$

t being reckoned above 212 Fahr. and F being the force in inches of mercury. Hence we get inversely:

$$t = \frac{F^{\frac{1}{7}} - 1}{.0029}$$

For very small changes of temperature, Dr Young's formula becomes

$$t = 1.642e$$

e being the corresponding slight variation of pressure from 30 inches, which corresponds, within three-thousandth parts, with the mean between Deluc's correction 1.598, and Shuckburg's 1.70, or 1.645 e .

Notwithstanding the simplicity of the form of this expression, and the facilities which it presents for ready calculation, it is impossible to adopt it, as it deviates widely and rapidly from the results of observation when extended to high temperatures. Induced, however, by the simplicity of the expression, and not a little influenced, it may be, by the high authority of a name that will ever be distinguished among the most distinguished of those who have contributed immortal truths to the treasures of physical science, the example of Dr Young has drawn after it many followers. Southern, Creighton, Coriolis, Tredgold, Arago, and Dulong, have successively attempted to modify the formula of Young, so as to twist it into some measure of conformity with observed phenomena—we shall see with how little success.

45. Mr Creighton adopted a similar formula to represent Ure's experiments, only changing the constant exponent from 7 to 6; so that, making F the force of steam in inches of mercury — 0.09, and the temperature of Fahrenheit + 85° = t , we have

$$F = \left(\frac{t}{168.878} \right)^6 \dots K.$$

$$\text{Log. } F = (\text{Log. } t - 2.22679)^6$$

46. Mr Southern represented his experiments by the formula

$$F = \frac{(t+51.3)^{5.13}}{87344.000000} + 0.1 \dots L.$$

Or,

$$\text{Log. } (1.1F) = 5.13 \text{ Log. } (t+51.3) - 10.94123$$

And,

$$\text{Log. } (t+51.3) = \frac{\text{Log. } (F+0.1) + 10.94123}{5.13}$$

47. Mr Tredgold simply reinstated Creighton's exponent, altering the co-efficient to bring it nearer to those experiments with which he was acquainted when his work was written; but it is inaccurate at high temperatures, and like that of Creighton.

$$F = \left(\frac{t+100}{177} \right)^6 \dots M.$$

48. To adapt the formula to more recent experiments, M. Coriolis (in his work *Du Calcul de l'Effet des Machines*, 4to, 1829) changed the exponent to 5.355, making it in French measures,

$$F = \left(\frac{1+0.01878t}{2.878} \right)^{5.355} \dots N.$$

reckoning from 0° cent. in atmospheres of 0.76 metres of mercury.

49. The French Academy of Sciences have finally reduced the index to 5.; finding that number represent their experiments at high temperatures, they adopted the following expression:

$$F = (1 + 0.7153t)^5 \dots O.$$

to give the elasticity in atmospheres of 0.76 metres, the temperature being in centesimal degrees, of course

$$t = \frac{F^{\frac{1}{5}} - 1}{0.7153}$$

50. In conclusion, the committee of the Franklin Insti-

Steam.
 Dr
 Young's
 Formula.

Southern's
 Formula.

Tredgold's
 Formula.

Coriolis's
 Formula.

Formula
 of the
 French
 Academy

Steam. tute have found it necessary to reinstate the index 6, of
Formula of the Franklin Institute. Creighton, only modifying Dr Young's constant multiplier, so as to obtain

$$F = (0.00333t+1)^6 \dots\dots\dots P.$$

51. It may be useful to collate these formulæ, and for this purpose they are assimilated in notation as follows—
F being the elastic force due to a certain temperature *t*.

Robison's Formula.

$$\text{Log. } F_t = m t \dots\dots\dots A.$$

Prony's Formula.

$$F_t = \mu \rho^t + \mu' \rho^{t^2} + \mu'' \rho^{t^3} + \&c. \dots\dots\dots B.$$

Laplace's Formula.

$$F_t = 0.76. (10)^{t.0,0154547 - t^2.0,0000625826} \dots\dots\dots C.$$

Biot's Formula.

$$F_t = 0.76. (10)^{At + Bt^2 + Ct^3} \dots\dots\dots D.$$

Ivory's Formula.

$$F_t = 30. (0.0087466t - 0.000015178t^2 + 0.0000002483t^3) \dots\dots\dots E.$$

Schmidt's Formula.

$$F_t = t^{1.163 + 0.021t} \dots\dots\dots F.$$

Soldner's Formula.

$$F_t = \log. 30.13 - \frac{(662-t)(212-t)}{52042} \dots\dots\dots G.$$

Roche's Formula.

$$F_t = 760.10 \frac{m t}{11 + 0.03t} \dots\dots\dots H.$$

Dr Thomas Young's Formula.

$$F_t = (0.0029t + 1)^7 \dots\dots\dots I.$$

Creighton's Formula.

$$F_t = \left(\frac{t}{16.57}\right)^6 \dots\dots\dots K.$$

Southern's Formula.

$$F_t = \frac{(t+51.3)^{5.15}}{87344,000,000} + 0.1 \dots\dots\dots L.$$

Tredgold's Formula.

$$F_t = \left(\frac{t+100}{177}\right)^6 \dots\dots\dots M.$$

Coriolis' Formula.

$$F_t = \left(\frac{0.01878t+1}{2.878}\right)^{5.555} \dots\dots\dots N.$$

Commission of the French Academy.

$$F_t = (0.7153t+1)^5 \dots\dots\dots O.$$

Committee of the Franklin Institute.

$$F_t = (0.00333t+1)^6 \dots\dots\dots P.$$

Examina- 52. From his earlier experiments Dr Dalton constructed
tion of the a scale of true temperature, in which the point of freezing
Law of the mercury is placed at 175°, and in the method he there
Elastic adopts, the increments of the scale of true temperature are
Force of as the square roots of the corresponding expansions of the
Steam. mercury from its point of maximum density. This scale
was soon made the subject of a close experimental scrutiny by Messrs Dulong and Petit, and afterwards of less accurate, though more acrimonious, strictures by Dr Ure.

This scale was, in fact, slightly inaccurate, because it was founded on the comparatively incorrect data of the experimental physics of that date. It is, however, scarcely fair to institute a comparison between the results of a theory based on certain phenomena and the results of experiments which the improvement of our knowledge has entirely altered. It were less unjust to the theory, and more wise as regards the interest of philosophy, first to examine how far it would have been modified by recent discoveries and then to compare its

results with the legitimate consequences of the data on which it rests. It ought also to be recorded, that Dr Dalton published, in the third part of his *Chemical Philosophy* in 1827, the corrected experimental results to which he had been conducted by the improved methods of observation, and the increased experience of thirty years which had elapsed from his first experiments, while modern writers continue to use the old numbers which should have been altogether discarded.

Adopting, then, Dr Dalton's recent experiments below the point of ebullition of water, and the experiments of the French and American Institutes above that point to 24. atmospheres, let us see what theory the views of Dr Dalton would conduct us to, setting out from these improved data.

Now, Dr Dalton found that, in his experiments, a certain progression of temperatures was accompanied by a certain progression of elastic force; but his range of experiment being too small, he adopted an erroneous progression, by which, reckoning this progression as rising from the freezing point of mercury, and proceeding as the square roots of the equal expansions of mercury above that point, gave 175° as the point corresponding to the zero of the scale and the origin of his progression.

53. In examining this subject again, I have found that this gradation of temperatures, though not exact in truth, is analogous to one which may be deduced from the best experiments—and equally from Dr Dalton's and those of the French Academy. The law at which I have arrived is this—that if we reckon the temperatures from the point of congelation of mercury in a logarithmic series, the elastic force of steam forms a similar geometric series to these intervals of temperature. This would indicate that equal intervals of temperature are those which expand the substance of the thermometer through equal fractional parts of its bulk, instead of equi-differential parts as at present, so that, instead of the common arithmetical series as at present, viz.,

$C + d + 2d + 3d + 4d + \dots\dots\dots n d \dots\dots\dots \alpha$
we should have the temperatures represented by the geometrical series

$(C+d) \cdot (1+d^2+d^3+d^4+\dots\dots d^n) \dots\dots\dots \beta$
and then the corresponding elasticities would be the geometrical series

$$(F+h) \cdot (1+h^2+h^3+h^4+\dots\dots h^n) \dots\dots\dots \gamma$$

54. Let us, therefore, endeavour to obtain the values of two such series, so as to coincide with the best experiments. For this purpose we put the series γ into the form

$$a m^n = f \dots\dots\dots \delta$$

and the series representing the progression of temperatures into the form

$$\frac{t}{r} = p^q \dots\dots\dots \epsilon$$

then since (δ)

$$\text{Log. } a + \log. m.n = \log. f$$

or making a the unit of pressure, for simplicity, we get

$$n = \frac{\log. f}{\log. m}$$

whence by substitution in ϵ when $q=n$, that is, when the elastic force is that which corresponds to the temperature q , we get

$$\frac{t}{r} = p \frac{\log. f}{\log. m} \dots\dots\dots \zeta$$

therefore

$$\text{Log. } t = \frac{\log. p}{\log. m} \cdot \log. f + \log. v \dots\dots\dots \eta$$

and

Steam. Examination of the Law of the Elastic Force of Steam.

Steam.
Examina-
tion of the
Law of the
Elastic
Force of
Steam.

$$\text{Log. } f = (\text{log. } t - \text{log. } v) \frac{\text{log. } m}{\text{log. } p} \dots \dots \dots \theta$$

When, therefore, p and r are determined for a given value of m , the relative is obtained. If we take the value $m = 2$, and if we take from the experiments of the French Academy and Franklin Institute, values of t and f above and below 30 inches, or unity, which is the value of m , and let these values be t', t'', f', f'' ; then from (ζ) we have

$$\left(\frac{t'}{r}\right)^{\frac{1}{\text{log. } f'}} - \left(\frac{t''}{r}\right)^{\frac{1}{\text{log. } f''}} = 0$$

and

$$\text{log. } \left(\frac{t'}{r}\right) \text{log. } f' - \text{log. } \left(\frac{t''}{r}\right) \text{log. } f'' = 0 \dots \dots i$$

We have only, therefore, to assume r so as to satisfy these conditions. Now,

$$\frac{t}{r} = \frac{t^{\text{Fahr.}} + c}{212 + c}$$

that is to say, if we reckon temperature from some given point c above or below the usual zero, viz. at the freezing point of mercury, like Dr Dalton's scale of temperature, and use the elastic force at 212° as our unit of pressure, we have then only to take f' and f'' from the tables of experiment, and give such a value to c as will satisfy the conditions. But as Dr Dalton places that zero at 175° we get

$$\frac{t}{r} = \frac{t^{\text{Fahr.}} + 175^\circ}{387}$$

We have still to find p the index of progression, corresponding to the values of f' and f'' in the experiments.

If we take the value of $m = 2$, then since by ζ

$$\left(\frac{t}{r}\right)^{\frac{\text{log. } m}{\text{log. } f}} = p$$

New Formulae. From the French experiments we get $p = 1.103$, whence by substitution, r being $= 387^\circ$, $p = 1.102$, $m = 2$, we have

$$\frac{t + 175^\circ}{387^\circ} = (1.103)^{\frac{\text{log. } F}{\text{log. } 2}} \dots \dots \dots R.$$

From Dr Dalton's experiments we get

$$r = 387^\circ, \quad p = 1.1320, \quad m = 2.602,$$

whence

$$\frac{t + 175^\circ}{387^\circ} = (1.1320)^{\frac{\text{log. } F}{\text{log. } 2.602}} \dots \dots \dots S.$$

From the combination of Dr Dalton's experiments below 30 inches, with the mean between those of the French Academy and the Franklin Institute, we get

$$r = 330^\circ, \quad p = 1.11401, \quad m = 2.0,$$

whence

$$\frac{t + 121^\circ}{333^\circ} = (1.11401)^{\frac{\text{log. } F}{\text{log. } 2}} \dots \dots \dots T.$$

It is from equation S and equation T that we have constructed the large table (Art. 56) in which the results of these formulæ are compared with experiment; the formula for high-pressure steam being compared with the mean of the French and American experiments; but, as they do not extend below 212°, that part is compared with Dr Dalton's table. The coincidence of these formulæ with experiment turns out to be much closer than could possibly have been expected where the discrepancies of experiments from each other are so great. The experiments of Dr Ure deviate from those of Dr Dalton, below

the pressure of the atmosphere, as much as .33, and the greatest deviation of the formulæ is .08. At pressures above the atmosphere the maximum deviation in the first ten atmospheres between the French and American experiments amounts to 6.4°, while the maximum deviation of the formulæ is only 1.1°.—

It is, however, remarkable, that in all the experiments hitherto made, the law of elasticity below the atmospheric pressure appears to deviate considerably from that above the atmosphere—perhaps it may arise from the circumstance that the experiments below atmospheric pressure have been made with different apparatus, having errors of a different kind from those made at high pressures above the atmosphere.

From these equations we easily deduce the following formulæ in a shape convenient for calculation.

$$\begin{array}{l} \text{Below } 212^\circ \\ \text{or one at-} \\ \text{mosphere.} \end{array} \left\{ \begin{array}{l} \text{Log. } F = 7.71307 (\text{log. } - 2.587711) \\ \text{Log. } t = 0.12965. \text{log. } F + 2.587711 \\ \text{when } t = t^{\text{Fahr.}} + 175^\circ \end{array} \right\} S^2$$

$$\begin{array}{l} \text{Above } 212^\circ \\ \text{or one at-} \\ \text{mosphere.} \end{array} \left\{ \begin{array}{l} \text{Log. } F = 6.42 (\text{log. } t - 2.5224442) \\ \text{Log. } t = 0.1557634. \text{log. } F + 52.244422. \\ \text{when } t = t^{\text{Fahr.}} + 121^\circ \end{array} \right\} T^2$$

These formulæ converted into rules are as follows:—

To find the pressure corresponding to any given temperature of steam above 212°—

Rule. To the temperature add 121°, find the logarithm of that sum, subtract from this logarithm the number 2.5224442, and multiply the remaining number by 6.42, the product is the logarithm of the pressure in atmospheres of 30 inches of mercury.

To find the temperature of steam, having any given pressure greater than that of the atmosphere—

Rule. Find the logarithm of the pressure in atmospheres, multiply it by 0.1557634, add to the product 2.5224442; the sum is the logarithm of the temperature, from which, if 121° be subtracted, the remainder will be the temperature on the common scale.

Example. To find the temperature at which high pressure steam will exert a force greater than the atmosphere by 195 lbs. on the inch—

$$195. \text{ lbs.} = 390. \text{ inches of mercury,}$$

$$390. \text{ inches of mercury} = 13. \text{ atmospheres,}$$

$$\therefore 14 \text{ atmospheres} = \text{total elastic force of the steam.}$$

$$\text{Logarithm of } 14 \dots \dots 1.1461280$$

$$.1557634$$

$$11461280$$

$$5730640$$

$$573064$$

$$80227$$

$$6876$$

$$342$$

$$44$$

$$.17852473$$

$$\text{Add } 2.5224442$$

502.306 is the number of which 2.7009689 is the log.
121. being subtracted

381.306° is the temperature on Fahrenheit's scale at which the elastic force of steam has a pressure of 14 atmospheres; an elastic force of 13. $\times$ 15. lb. excess of pressure above the atmosphere on each square inch, = 195. lbs.

To find the pressure corresponding to any given temperature of steam below 212°—

Rule. To the temperature add 175°, find the logarithm of that sum, subtract from this logarithm the number

Steam.
New
Formulae.

New
Rules.

Steam. 2.587711, and multiply the remainder by 7.71307; the product is the logarithm of the pressure in decimal parts of an atmosphere; which, if multiplied by 15. will give pounds on the square inch, and by 30. inches of mercury.

To find the temperature at which steam will have a given elastic force less than that of the atmosphere—

Rule. Find the logarithm of the pressure in decimal parts of an atmosphere, multiply it by 0.12965, add to the product 2.5877110; the sum is the logarithm of the temperature which will be expressed in degrees of Fahrenheit's scale, if 175. be subtracted from it.

Example. To find the pressure of steam at 175°.

To	170°
Add	175°
The sum is 345°, of which the log. 2.5378191	
	subtract 2.5877110
	the remainder 1.9501081
	multiplied by 7.71307
	6.6507567
	6650756
	95010
	28503
	6650
	—(7.71307)

The next No. is 0.412837, its log. 1.6157786
30

12.384 inches of mercury is the pressure;
being 17.616 inches of mer. below the atmos.
30.000

By these rules the following table is calculated.

Table of the Elastic Force of Vapour in inches of Mercury, at different temperatures, according to our Formulae S² below 212° and T² above it.

0° 0.07	62° 0.68	96° 1.89	130° 4.78
10 0.10	63 0.70	97 1.96	131 4.91
20 0.15	64 0.72	98 2.01	132 5.03
30 0.22	65 0.74	99 2.08	133 5.15
*32 0.24	66 0.77	100 2.15	134 5.28
33 0.25	67 0.80	101 2.21	135 5.41
34 0.26	68 0.82	102 2.28	136 5.55
35 0.27	69 0.85	103 2.34	137 5.70
36 0.28	70 0.88	104 2.41	138 5.84
37 0.29	71 0.91	105 2.48	139 5.98
38 0.30	72 0.94	106 2.55	140 6.13
39 0.31	73 0.97	107 2.62	141 6.29
40 0.32	74 1.00	108 2.69	142 6.45
41 0.33	75 1.03	109 2.76	143 6.61
42 0.34	76 1.06	110 2.83	144 6.76
43 0.35	77 1.09	111 2.91	145 6.92
44 0.37	78 1.12	112 2.98	146 7.08
45 0.38	79 1.16	113 3.08	147 7.25
46 0.39	80 1.20	114 3.16	148 7.41
47 0.40	81 1.24	115 3.25	149 7.61
48 0.42	82 1.28	116 3.33	150 7.80
49 0.43	83 1.31	117 3.42	151 8.00
50 0.45	84 1.36	118 3.51	152 8.20
51 0.47	85 1.39	119 3.60	153 8.40
52 0.49	86 1.44	120 3.69	154 8.59
53 0.51	87 1.47	121 3.79	155 8.79
54 0.53	88 1.51	122 3.88	156 8.99
55 0.55	89 1.56	123 3.98	157 9.20
56 0.57	90 1.61	124 4.08	158 9.41
57 0.59	91 1.65	125 4.19	159 9.62
58 0.61	92 1.69	126 4.30	160 9.84
59 0.62	93 1.74	127 4.42	161 10.06
60 0.64	94 1.79	128 4.53	162 10.28
61 0.66	95 1.84	129 4.66	163 10.51

164° 10.75	192° 19.86	220° 35.35	248° 58.48
165 11.01	193 20.30	221 36.08	249 59.37
166 11.28	194 20.74	222 36.80	294.7 60.00
167 11.56	195 21.19	223 37.54	250. 60.27
168 11.85	196 21.64	224 38.31	274.1 90.00
169 12.05	197 22.11	225 39.11	291.9 120.00
170 12.36	198 22.57	226 39.94	306.8 150.00
171 12.66	199 23.04	227 40.70	319.2 180.00
172 12.96	200 23.52	228 41.66	329.9 210.00
173 13.26	201 24.00	229 42.55	339.3 240.00
174 13.56	202 24.50	230 43.46	348.8 270.00
175 13.86	203 25.00	231 44.29	355.6 300.00
176 14.16	204 25.52	232 45.14	363.0 330.00
177 14.47	205 26.05	233 45.95	369.4 360.00
178 14.78	206 26.59	234 46.78	375.5 390.00
179 15.09	207 27.14	235 47.58	381.3 420.00
180 15.41	208 27.69	236 48.39	387.0 450.00
181 15.73	209 28.25	237 49.21	391.9 480.00
182 16.06	210 28.83	238 50.04	396.7 510.00
183 16.40	211 29.40	239 50.86	401.3 540.00
184 16.75	*212 30.00	240 51.70	405.8 570.00
185 17.10	213 30.61	241 52.53	410.0 600.00
186 17.46	214 31.24	242 53.37	444.6 900.00
187 17.83	215 31.89	243 54.22	470.5 1200.00
188 18.21	216 32.56	244 55.07	491.4 1500.00
189 18.60	217 33.24	245 55.93	
190 19.00	218 33.93	246 56.73	
191 19.42	219 34.63	247 57.60	

Steam.
New
Table.

55. The formulæ thus given are in such perfect accordance with our best experimental knowledge, that we cannot withhold our assent from the correctness of the principles from which they have been deduced. At the same time, we desiderate very much a better series of experiments than we yet possess, as the range of doubtful temperature above 212° is far wider than the present perfect state of experimental science, and our improved means of observing, can at all warrant. The discrepancies between the experiments above and below 212° show, that the two series should if possible be performed with identical apparatus.

The formulæ we have obtained have been founded on the hypothesis, that bodies expand nearly equal proportions of bulk in equal intervals of true temperature; and we have found that the elastic force of steam increases in equal proportions, from equal increments of temperature, reckoned in true intervals from the bottom of the scale.

Our formula should, however, be capable of being reduced into a form closely resembling those which have preceded it, in so far as these have represented approximately the experiments they were made to represent; thus the formula of Laplace and his followers is of the form

$$F = C m t + m t^2 + m t^3 + \&c. \text{ ad infinit.}$$

So, in like manner, we should obtain from Equation T the following:

$$\text{Log. } 2 \times \left\{ 2 \log. c - \log. (c - t^0) - k \left(\frac{t}{c^2} + \frac{c}{2c^4} + \frac{t^6}{3c^6} + \&c. \right) \right\}$$

$$- \log. C - \log. (1.11401) \log. F = 0$$

which is easily presented in a form absolutely the same.

In like manner, it may be presented at once in the form adopted by Dr Thomas Young and all his followers, viz.

$$\left(\frac{m t + c}{c} \right) = F$$

for, if we take our formula S₂

$$\text{Log. } F = 7.71307 (\log. t - 2.587711)$$

we get, resuming the natural number,

$$F = \left(\frac{t + 175}{387} \right)^{7.715} \dots\dots\dots S_3.$$

Or, if we take formula T₂, we get

$$F = \left(\frac{t + 121}{333} \right)^{6.42} \dots\dots\dots T_3.$$

We thus find, that the old formulæ have all approximated in a greater or less degree to the representation of

the very hypothesis on which ours has now been formed. They thus add greatly to the probability of its truth. We do not, however, mean to assert, that the zero of the mercurial thermometer is absolutely at 175° or 121° below the present 0. or that the progression of the temperatures has been fixed accurately for mercury or for vapour. On the contrary, we have seen that the discrepancies of the results obtained by different physical experimenters are great, and do not admit of obtaining un-

changeable numerical indices of progression, either of the temperatures or the corresponding elastic force. The existence of these two progressions, and their character, has, we think, been established, and our research has the effect of confirming, the profound views of Dr Dalton, which have, we think, been ill understood and insufficiently appreciated.

56. The following table exhibits some formulæ and experiments collated:

Table of the force of Steam at different temperatures from 0° to 500°.

I. Tempera- ture. Fahrenheit.	II. Dalton.	III. Ure.	IV. Young.	V. Ivory.	VI. Tred- gold.	VII. South- ern	VIII. Robison.	IX. Watt.	X. Frank. Inst.	XI. New For- mula.	XII. Diff. Dalt. & Ure's Expts.	XIII. Diff. Acad. Inst.	XIV. Diff. Tred. & Dalton.	XV. Diff. New Formula & Dalton.	XVI. Tempera- ture. Fahrenheit.
0°	0.08	...	...	...	...	...	...	...	...	0.07	...	...	...	-.01	0°
10	0.12	...	...	...	...	...	...	...	...	0.10	...	...	...	-.02	10
20	0.17	...	0.11	...	...	...	...	...	...	0.15	...	...	-.09	-.02	20
32	0.26	0.20	0.18	...	0.17	0.16	0.00	...	...	0.24	-.06	...	-.10	-.02	32
40	0.34	0.25	0.20	...	0.24	0.22	0.10	...	...	0.32	-.09	...	-.11	-.02	40
50	0.49	0.36	0.36	0.36	0.37	0.33	0.20	...	...	0.45	-.13	...	-.10	-.04	50
60	0.65	0.52	0.53	...	0.55	0.48	0.35	...	...	0.64	-.13	...	-.09	-.01	60
70	0.87	0.73	0.75	0.73	0.78	0.68	0.55	0.77	...	0.88	-.14	...	-.05	+.01	70
80	1.16	1.01	1.05	...	1.11	0.95	0.82	...	...	1.20	-.16	...	-.06	+.04	80
90	1.59	1.36	1.44	1.36	1.53	0.34	1.18	...	...	1.61	-.23	...	-.04	+.02	90
100	2.12	1.86	1.95	...	2.08	1.84	1.60	1.55	...	2.15	-.24	...	-.00	+.03	100
110	2.79	2.45	2.62	2.46	2.79	2.56	2.25	...	...	2.83	-.34	...	+.05	+.04	110
120	3.63	3.30	3.46	...	3.68	3.46	3.00	...	...	3.69	-.33	...	+.10	+.06	120
130	4.71	4.37	4.54	4.41	4.81	4.43	3.95	...	...	4.78	-.34	...	+.16	+.07	130
140	6.05	5.78	5.88	...	6.21	5.75	5.15	5.14	...	6.15	-.27	...	...	+.08	140
150	7.73	7.53	7.55	7.42	7.94	7.46	6.72	...	...	7.80	-.20	...	+.21	+.07	150
160	9.79	9.60	9.62	...	10.05	9.52	8.65	8.92	...	9.85	-.19	...	+.26	+.06	160
170	12.31	12.05	12.14	12.05	12.60	12.14	11.05	11.37	...	12.38	-.26	...	+.29	+.07	170
180	15.38	15.16	15.23	...	15.67	15.20	14.05	14.73	...	15.41	-.28	...	+.29	+.03	180
190	18.98	19.00	18.96	18.93	19.00	...	17.85	19.00	...	18.90	+.12	...	+.02	+.02	190
200	23.51	23.60	23.44	...	23.71	...	22.62	...	...	23.52	+.09	...	+.20	+.01	200
210	28.82	28.88	28.81	28.81	28.86	...	28.65	...	...	28.82	+.07	...	+.04	+.00	210
212	30.00	30.00	30.00	30.00	30.00	30.00	30.00	29.40	...	30.00	0.00	...	+.00	0.00	212
220	35.18	35.54	35.19	...	34.92	...	35.8	33.65	...	35.10	-0.36	...	-.26	-.15	220
230	44.60	43.10	42.47	42.63	42.00	...	44.5	40.+	...	42.60	-1.50	...	-2.13	-2.00	230
240	53.45	51.70	51.66	...	50.24	...	54.9	49.0	...	51.42	-1.75	...	-3.21	2.03	240

Table of the Force of Steam at different Temperatures (continued).

I. Pressure in Atmos- pheres.	II. French Acad.	III. Dr Ure.	IV. Young.	V. Ivory.	VI. Tredg.	VII. South.	VIII. Robison.	IX. Watt.	X. Franklin Institut.	XI. New Form.	XII. Diff. Dr Ure's Ex- periments	XIII. Diff. Acad. Inst.	XIV. Diff. Tred. & Dalton	XV. Diff. New Form & Ac. Inst.	XVI. Pressure in Atmos- pheres.
1st At.	212.0°	212°	212°	212°	212°	...	212°	212°	212°	212°	0.00	000.2	0.00°	0.00°	1st At.
2d At.	250.5	250.0	240.3	249	250.+	250.3+	...	252.5	250.0	249.7	...	-0.5	0.+	-0.55	2d At.
3d At.	275.2	275.0	271	...	274.+	...	267	...	275.2	274.1	...	-0.2	-1.+	-1.0	3d At.
4th At.	293.7	291.5	288	290	294.+	293.4+	...	...	291.5	291.9	...	-2.2	+.14	-0.7	4th At.
5th At.	308.8	304.5	302	...	309.+	...	...	...	304.5	306.8	...	-4.3	+.37	-0.1	5th At.
6th At.	320.4	315.5	...	...	322.+	...	...	...	315.5	319.2	...	-4.9	+.40	+.12	6th At.
7th At.	331.7	325.5	...	...	...	...	...	...	326.5	329.9	...	-5.7	...	+.11	7th At.
8th At.	362.0	336.0	...	337	342.+	343.6+	...	...	336.0	339.3	...	-6.0	+.33	+.03	8th At.
9th At.	374.8	345	...	...	...	...	...	...	345.0	348.8	...	-5.0	...	+.09	9th At.
10th At.	358.9	...	...	...	...	...	...	...	352.5	355.6	...	-6.4	...	-0.1	10th At.
11th At.	366.8	...	...	...	...	...	...	...	...	363.0	...	...	...	...	11th At.
12th At.	374.0	...	...	...	372.+	...	...	...	...	369.4	...	...	+.3.0	...	12th At.
13th At.	380.6	...	...	...	...	...	...	...	...	375.5	...	...	...	...	13th At.
14th At.	386.9	...	...	...	...	...	...	...	...	381.3	...	...	...	...	14th At.
15th At.	392.8	...	...	...	...	...	...	...	383.8	387.0	...	-9.0	...	-0.3	15th At.
16th At.	398.5	...	...	...	...	...	...	...	...	391.9	...	...	...	...	16th At.
17th At.	403.8	...	...	...	...	...	...	...	...	396.7	...	...	...	...	17th At.
18th At.	408.9	...	...	...	...	...	...	...	...	401.3	...	...	...	...	18th At.
19th At.	413.9	...	...	...	...	...	...	...	...	405.8	...	...	...	...	19th At.
20th At.	418.5	...	...	...	414	...	...	...	405	410.	...	-13.5	+.2.3	-1.7	20th At.
30th At.	457.2	...	...	...	...	...	...	...	...	444.6	...	...	...	...	30th At.
40th At.	466.6	...	...	...	...	...	...	...	...	470.5	...	...	...	...	40th At.
50th At.	510.6	...	...	...	...	...	...	...	...	491.4	...	...	...	...	50th At.

The first and last columns contain the successive temperatures, as far as 240°, and after that the number of atmospheres of pressure; and their reference extends wholly across the table.

Col. II. contains the later experiments of Dr Dalton, interpolated, where necessary, down to 240°; the remainder of that column is from the experiments of the French Academy.

Col. III. contains the experiments of Dr Ure.

Cols. IV. V. and VI. contain the formulæ of Dr Young, Mr Ivory, and Mr Tredgold.

Cols. VII. VIII. IX. and X. contain the experiments of Southern, Robison, Watt, and the Franklin Institute.

Col. XI. contains the numbers given by our formulæ.

Col. XII. exhibits the differences between the experiments of Drs Dalton and Ure.

Steam.
Compara-
tive Tables
of Elastic
Force.

Steam.
Comparative Tables
of Elastic
Force.

Col. XIII. exhibits the differences between the experiments of the French Academy and the Franklin Institute.

Col. XIV. exhibits the deviations of Tredgold's formula from Dalton's experiments, down to 240° ; and below that point, from the mean of the experiments of the French Academy and the Franklin Institute, interpolated where required.

Col. XV. exhibits the difference between our formulæ and the best experiments, Dr Dalton's being taken down to 240° ; and the mean between those of the French Academy and the Franklin Institute from that point to the end of the table—interpolations being used when necessary.

SECTION IV.—ON THE CONSTITUTIONAL CALORIC OF STEAM, ITS DENSITY AND VOLUME AT DIFFERENT TEMPERATURES, AND ITS GENERATION AND CONDENSATION.

Constitution of
Steam.

57. Having now ascertained the force that may be given to steam by heating water in a confined space, so that we can always obtain any force we desire by raising it to the proper temperature, we have next to enquire what quantity of heat is necessary to produce steam of that temperature and force. The answer to this question is, to determine the quantity of fuel necessary to generate steam of a given power, and direct the economic application of that power.

The quantity of caloric necessary to transform a given quantity of water into steam of the same temperature, is called the *caloric of elasticity* of that substance. The quantity of heat which it will contain at any given temperature is called its *capacity* for heat; and the relation which subsists between the quantity of heat which some well-known body, such as water or air, gives out or acquires, in a given change of temperature, and that which any other substance will give out or acquire in the same circumstances, is called the *specific caloric* of that substance.

58. Of the quantity of the caloric of elasticity of any substance, of its capacity for containing heat, and of its specific caloric, the *thermometer* gives us no information. An instrument for doing so may be called, as a distinction, the *calorimeter*. Thus the thermometer measures the intensity of heat—the calorimeter its quantity.

Capacity
for Caloric.

If in three several vessels there be contained, at the temperature of 32° , a pound weight of three different fluids, water in one, mercury in the second, and oil in the third; and if the heat of an alcohol lamp be applied, first of all to the mercury, then to the water, and next to the oil, a thermometer being inserted in each, it will require much longer time to heat the water to 212° of the thermometer than the mercury, twenty-five times as much alcohol being burnt in the process; whereas the oil will be warmed to the same temperature on the thermometer, by half the quantity of caloric which is necessary to heat the water to 212° . Therefore, the capacity of water for heat is said to be twenty-five times as great as that of mercury, and twice as great as the capacity of oil; and the specific heats of these substances, in relation to water, are thus represented:

Water, 1.000; oil, 0.520; mercury, 0.040 nearly.

If, instead of taking equal weights of these substances, we had filled equal vessels with them, and then applied the quantity of water necessary to heat them to equal temperatures, we should have had the capacities and specific heat of equal volumes, instead of equal masses as formerly; and it would have been found, that the quantity of alcohol required to heat them to the same temperature, was only half as much for the mercury as the water, and greater for the water than the oil, in the proportion of 20 to 9; showing that the capacity of water was still the

greatest, and that the specific caloric, in equal volumes of these substances, are nearly

Water, 1.000; oil, 0.450; mercury, 0.550.

The capacities for heat, and the specific caloric of different substances, may be determined by cooling as well as heating them. An ounce of ice thrown upon a pound of mercury will cool it or an equal weight of oil much more than water; and, in general, the quantity of ice, or of cold water, or of cold air, or any other fluid required to cool a body, will exactly correspond to the quantity of caloric required to heat it to the same degree of temperature. A calorimeter measures the quantity of ice which must be melted in cooling different substances, and is described in our article "HEAT." The following are the results of such of the most valuable experiments upon this subject as are appropriate to our present enquiry:

Table of the specific Caloric in different substances.

	Equal Weights.	Equal Volumes.	
Water,	1.000	1.000	
Mercury,	0.033	0.470	Dulong and Petit.
Alcohol,	0.700	0.570	Dalton.
Sulphuric ether,	0.660	0.500	Dalton.
Spermaceti oil,	0.520	0.450	Dalton.
Olive oil,	0.309		Lavoisier & Laplace.
Sulphuric acid,	0.350	0.650	Dalton.
Nitric acid,	0.620	0.870	Dalton.
Muriatic acid,	0.600	0.700	Dalton.
Sol. of salt (1.197)	0.780	0.930	Dalton.
Sol. of sugar (1.117)	0.770	0.900	Dalton.
Ice,	0.900	0.830	Dalton.
Coal,	0.280	0.360	Dalton.
Flint glass,	0.190	0.550	Dalton.
Iron,	0.110	0.880	Dulong and Petit.
Copper,	0.095	0.850	Dulong and Petit.
Lead,	0.040	0.450	Dalton.
Tin,	0.070	0.510	Dalton.
Zinc,	0.100	0.690	Dalton.
Silver,	0.055		Dulong and Petit.
Gold,	0.029		Dulong and Petit.
Platina,	0.335		Dulong and Petit.
Atmospheric air,	0.267	1.000*	1.000*
Hydrogen gas,	3.294	12.340	8.903
Oxygen gas,	0.236	0.885	0.976
Nitrogen gas,	0.275	1.032	1.000
Nitrous oxide gas,	0.237	0.888	1.350
Olefiant gas,	0.420	1.576	1.553
Carbonic oxide gas,	0.288	1.080	1.034
Carbonic acid gas,	0.221	0.828	1.258

Delaroche and
Berard.

69. Besides the capacity of different bodies for heat, and the specific heat of each at given temperatures, there is another condition of heat still more striking, and of which the thermometer gives no indication. It is this: that the same substance, at different times, may contain different quantities of caloric, and yet the thermometer in both cases give the same indication of temperature. Ice at 32° , which is in the process of melting, and while its bulk is diminishing by one-tenth part, receives as much caloric as would raise its temperature, when melted, to 172° ; and after having received it all, remains still at the same temperature as before, indicating 32° on the thermometer. In like manner, when the particles of the water have acquired so much sensible heat as to raise its temperature to 212° , it may receive as much more heat as would have raised its temperature 950° or 960° , if it had continued to be shown by the thermometer; but the water now assuming the state of steam, the thermometer indicates no accession, but remains in the water or in the steam still at the temperature of 212° . In these two conditions, there-

* In these two columns air is assumed as unity, the first being the specific heat under equal weights, and the second under equal volumes.

Steam.
Specific
Heat.

Steam.
Specific
Heat.

fore, when the particles of ice are leaving the solid and taking the liquid form, and again passing out of the liquid into the vaporous state, a large accession of caloric passes into the substance without being detected by the thermometer; this heat, *insensible* to the thermometer, and manifested only by the calorimeter, is called **LATENT HEAT**. The doctrine of latent heat was discovered by Dr Black.

The quantity of heat thus latent in the mass of a solid, when it assumes the liquid state, is called the *caloric of fluidity*. The latent caloric of a liquid passing into vapour is called the caloric of elasticity or vaporization.

Caloric of Fluidity.		Caloric of Vaporization.	
Sulphur, . . .	144°	Water, . . .	967°
Spermaceti, . .	145	Alcohol, . . .	442
Lead, . . .	162	Ether, . . .	302
Bees' wax, . . .	175	Petroleum, . .	178
Zinc, . . .	493	Oil of turpentine,	178
Tin, . . .	500	Nitric acid, . .	532
Bismuth, . . .	550	Liquid ammonia,	837
Ice, . . .	140	Vinegar, . . .	875

Latent
Heat.

60. The determination of the latent heat of ordinary steam is a problem of considerable practical difficulty. It may be obtained rudely by very simple contrivances. If a lamp, which burns with tolerable uniformity, be applied to a vessel containing cold water, at the temperature of 32°, so long as to heat it to 212°, the boiling point, and if the lamp be then weighed and the consumption of oil ascertained by the loss of weight; and if the lamp be still applied to the boiling water so as to keep it constantly in ebullition until the whole has been converted into steam; the steam passing off at the same temperature as the water, it will be found, when the whole water has been boiled away, or converted into steam, that 6 times as much oil has been consumed, or that 6 times as much heat has been employed in the conversion of the water into steam as was required formerly to heat the water from 32° to 212°, or to give it 180° of temperature; so that 6 times 180° or 1080°, will appear to have been absorbed or carried off in the steam of 212°—that is, the latent heat of steam is 1080°.

Otherwise, the same determination may be obtained, if the steam, when passing off from the boiling water, be led carefully in a pipe to a vessel of cold water, so as to take from it the heat which it has thus carried off; if the water to which the heat of the steam is given out be at a temperature of 32° and of 6 times the quantity of the water from which the steam was formed, the whole of it will be heated by the caloric of the steam to 212°, showing that the quantity of caloric of the steam amounts to what gives 180° to 6 times the quantity of water; giving, as formerly, 6 times 180° or 1080° as the amount of the latent heat of the steam.

It is to Mr Watt that we owe the earliest determination of the latent heat of steam. Dr Black endeavoured to ascertain this point by the first of the methods we have pointed out, by comparing the time of raising the temperature of water a certain number of degrees, with the time of boiling it off a certain number of degrees; but his result was not correct, being only 800°. Mr Watt's result for the latent heat of steam was 1006° 79.

Mr Southern's experiments were made in 1803; and he was assisted in them by Mr William Creighton, and communicated them to Mr Watt for an appendix to this article. He obtained the number 950°. The thermometers employed in his experiments were made and graduated with the greatest care, the tubes having been accurately measured as to the proportional capacity of their different parts.

A similar series of experiments was afterwards made by M. Schmidt, who determined the heat latent in steam to be about 5.33 times that necessary to heat water from 32° to 212° = 5.33 times 180° or 960 nearly.

VOL. XX.

Count Rumford determined the latent heat of steam by condensing it in a calorimeter formed by pushing a long spiral steam pipe through a vessel of cold water, by which he obtained 1040.8 as the latent heat of steam of water.

M. Despretz in the *Annales de Chimie et Physique*, gives 955.8° as the result of his experiments on the latent heat of steam.

Lavoisier and Laplace make the latent heat of steam 1000°.

From the experiments of Gay Lussac and of MM. Clement and Desormes, the number 990° is generally used by the French to represent the latent heat of steam. The diversity of the results obtained from experiments made by so many excellent experimenters, with so much precaution, is remarkable—to eliminate from them the precise truth with certainty is not within our present resources of analysis. There is high probability in favour of the numbers 990. or 1000., as representing nearly enough the latent heat of steam, being 5.555 times the caloric of boiling water, its whole caloric reckoned from 32° being 6.666 times that of boiling water.

61. A doctrine of great simplicity is now pretty generally held as expressing with an accuracy quite within the limits of experimental precision, the result of our knowledge of the heat latent in steam. It is found that in steam of great elasticity and of corresponding high temperature, the heat latent is in quantity less; and that, on the contrary, when steam is of lower elastic force and of lower temperature than at 212°, its latent heat is greater than at 212°. And it appears that we are warranted in the conclusion first suggested by Mr Watt and afterwards by Dr Dalton, that the whole amount of caloric in a given quantity of elastic vapour remains the same at all temperatures and under all pressures. When the volume of the vapour is great the greater is its capacity and the less its temperature; while, by compressing it into smaller space, its elasticity is encreased and its temperature raised. The doctrine is thus expressed, *that the sum of the sensible and latent heat of vapour is a constant quantity*. M. Despretz has extended this to the vapours of several other fluids.

There is another expression for the law of the constitutional heat of the vapour, which is, in the language of the Atomic Theory, *that every atom of a fluid in the state of vapour possesses, under every degree of elasticity and pressure, the same quantity of caloric*. This doctrine leads to very important consequences both of a theoretical and practical nature.

It follows immediately from this doctrine, that if a quantity of vapour have once been formed by adding to the liquid the quantity of caloric necessary to the constitution of the vapour, the same particles of matter surrounded by the same spheres of caloric may pass through all gradations of density, and through all gradations of temperature, without either parting with caloric or obtaining fresh supplies. Vapour of the temperature of 212°, as it rises from water boiling in the open air, may be collected in a vessel and compressed by the force of 30 inches of mercury into half its bulk, it will become steam of a higher temperature, viz., 250° from the increased quantity of caloric in the diminished volume, and in this case the latent heat will only be 970° instead of 1000°. If compressed still further into again one half of that bulk, the temperature will rise to 292°, and leave only 920° latent. Compressed still further into half of the last-mentioned space, that is into $\frac{1}{8}$ of its original bulk, the temperature is raised to 339°, leaving only 873° latent; and another step would raise the temperature to 392°, leaving only 820° latent; less than seven steps more would bring the steam into less than its original bulk of water, with a temperature of between 900° and 1000° of sensible heat, and

4 G

Steam.
Latent
Heat.

Steam.
Latent
Heat.

an amount of latent heat not much greater than its original proportion of sensible heat, or 212° . In this case, we should have steam as heavy as water and as hot as flame.

If, on the contrary, this process were reversed, and the steam produced at 212° under the pressure of an atmosphere permitted to expand in vacuo to double its bulk, a portion of the sensible heat would become absorbed into the spheres of caloric around the atoms of water, increasing the latent heat by 32° , and diminishing the sensible heat to 180° . The bulk being again doubled, and the steam expanded to four times its original bulk, the temperature would sink to 150° , and three more repetitions of the expansion would give a vapour of 71° temperature, and 1141° of latent heat.

This expansion and contraction of the steam, accompanied by diminished temperature, is exactly what would exist if our atmosphere, instead of oxygen and nitrogen, were wholly composed of vapour of water. Suppose the temperature of the ocean to be 1000 , an atmosphere of vapour would be raised of 2000 times the weight of the present atmosphere: the under part of this atmosphere, compressed by the superincumbent weight, would be of great density, but in ascending, the diminished pressure would be attended with diminished temperature, until at last a cloud of white ice would be seen floating on the surface. Must not the sun, from his intense heat, be a body of this nature, having an atmosphere of enormous depth, on the summit of which the beautifully crystalline and sparkling crust is continually preserved by its diminished temperature in a state of renewed whiteness?

Specific
gravity,
density,
and volume
of Steam.

62. The specific gravity, density, and volume occupied by steam at different temperatures, have been correctly determined by experiment; and it has been ascertained that the expansion of vapour follows the law of the expansion of other gases by heat; viz., the law of Dalton and Gay Lussac, that all gases expand from 1 . to 1.375 in bulk, by 180° of temperature, or $\frac{1}{480}$ for each degree of Fahrenheit; and, secondly, that steam obeys the law of Boyle and Mariotte, contracting in volume proportionally to pressure. It is first of all necessary to know what bulk a given quantity of water converted into steam will occupy at a given pressure, and the application of these laws will determine the specific gravity, density, and volume at all other pressures and temperatures.

Gay Lussac's experiments,

63. The experiments of Gay Lussac upon this subject are simple, elegant, and satisfactory. His apparatus is as follows:—A chauffer, F, contains burning fuel, by which heat is communicated to B C, a bath of mercury. A spherule A, of thin glass, hermetically closed, contains a given weight of water. G is a glass tube of considerable diameter, filled with pure dry mercury, and inserted in the bath, after which the spherule, A, containing the water, is allowed to ascend to the top of the mercury, and is then broken by concussion, so that a given quantity of water is thus placed in the Torricellian vacuum at the top of the mercury. By the fuel in F heat is then communicated upwards, by the fluids, to the whole apparatus, and to the water in the summit of the tube G; and the mercury descends until the whole of the water is converted into steam, after which it ceases to descend in the same rapid proportion to the increase of temperature. This change shows that the whole of the water is evaporated, and the heat must again be allowed gradually to diminish, until the depression of the mercury corresponds to the temperature indicated in our table of Elastic

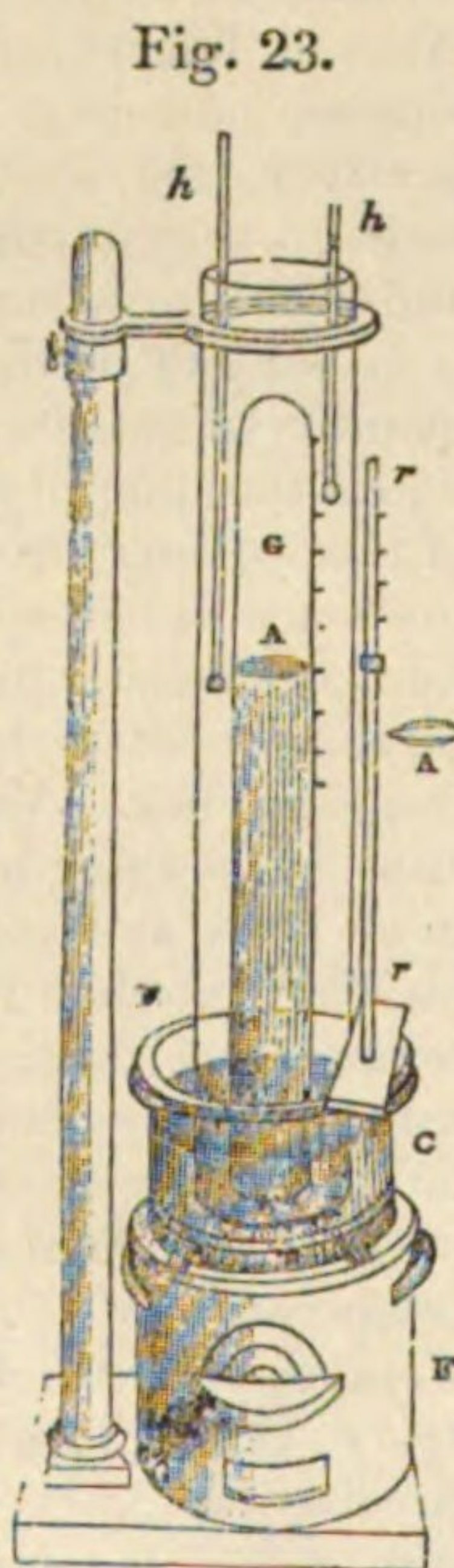


Fig. 23.

Force. The capacity of the tube, G, is shown by divisions on its surface previously fixed, and the height of the mercurial column by a graduated rule and vernier $r r$, supported on the edge of the bath. The thermometers, $h h$, indicate the temperature of the fluids.

By means of this apparatus, Gay Lussac has determined the specific gravity of steam, to be $.625$, air being 1000 ; that is to say, steam from boiling water is lighter than common air in the proportion of 5 . to 8 .

64. Dr Dalton's recent experiments make the weight of a cubic foot of air at $60^{\circ} = 535.68$ grains; therefore a cubic foot of common steam weighs 334.8 grains at 60° , under a pressure of 30 inches of mercury; but as this pressure would convert it into water, the true weight will be found, by the law of Mariotte, thus:

$$30 \text{ in.} : .065 :: 334.8 : 7.254$$

the true weight, in grains, of a cubic foot of steam at 60° , and under the former pressure due to its own elasticity in vacuo; but if we wish to know the weight of a cubic foot of steam at 212° , we must use the law of Gay Lussac and Dalton, thus:

$$\frac{(212^{\circ} - 60^{\circ}) \text{ or } 152^{\circ}}{480} + 1 : 1 :: 334.8 : 254.3$$

254.3 grains is, therefore, the weight of a cubic foot of steam, as it passes off from water boiling in the air at 212° .

But the weight of one cubic inch of water at 60° is 253 grains; therefore, the weight of a cubic inch of water at 60° is almost exactly equal to one cubic foot, or 1728 cubic inches, of steam.

Hence we find, that the particles of water, when they form steam, are so much repelled by their spheres of caloric, as to be kept at twelve times their original distance from each other; that, in this gaseous state, water is 1728 times rarer than when liquid; and that one gallon of water, with the requisite supply of caloric, will make 1728 gallons of steam.

65. The source from which caloric is obtained for the conversion of water into steam, is either the heat of the sun, the central heat of the earth, or of artificial fires. It is upon the intensity and quantity of this heat that the elastic force, temperature, density, and volume of the steam obtained for any particular purpose must depend; and it is therefore an important point to determine how it is to be obtained.

The most important and common sources of heat for the production of steam, are the combustion of coal, charcoal, wood, resin, and oil. Many experiments have been made upon the quantities of caloric given out during their combustion; but the results vary much with the methods of applying the heat. The six following are some of the results of Dr Dalton's experiments; the rest are selected from the best authorities:

One lb. of Hydrogen, burnt with 7 lbs. oxygen, produces 8 lbs. of water, and raises 250 lbs. of water 180° .

Charcoal,	2.8	3.8 carbon. acid,	31 lbs.
Oil, wax, tallow,	3.5	4.5 water and carb. ac.,	81
Oil of turpentine,			46.4
Carburetted hydrogen,	4.	5. water and carb. ac.	66
Olefiant gas,	3.5	4.5 water and carb. ac.	67
Naphtha,	3.20		73
Rape oil,			90
Caking coal,			54
Olive oil,			76
Charcoal,			57
Coke,			51
Peat,			22
Newcastle coal,			55.5
Culm,			11

The numbers in the last column represent the number of pounds of water at 32° , which will be heated to 212° , when the fuel is applied in the most economical manner; and hence the quantity of fuel to heat any other quantity

Steam.
Density of
Steam.

Dr Dalton's experiments.

Steam. of water any number of degrees, can be found by the common arithmetical rules of proportion.

Steam pro- The quantity of water at 212°, which will be converted into steam, may be found, by dividing the number of pounds of water in the table by 5.55. Thus, from the table—

1 lb. of Newcastle coal gives 180° to 55.5 lbs. of water.

Therefore, 1 lb. of Newcastle } $\frac{55.5}{5.55} = 10$ lbs. of water.
coal converts into steam, }

This is to be taken as the effect that may be produced if there be no material loss of heat; and in the Cornish engines I find that even 10.5 lbs. are actually accomplished.

In general, however, for the purposes of ordinary manufactures, in Lancashire, Staffordshire, and the vicinity of London, it appears that not more than 6.6 lbs. of water are converted into steam by one pound of coal; so that not more than 33.3 lbs. of water are heated with ordinary boilers from 32° to 212°. The following table may be taken as the numbers usually given to represent the actual state of practice. But a late investigation by Mr Parkes shows, that in the best constructions of boilers now used in Cornwall, Warwickshire, and elsewhere, these effects are nearly doubled:

1 lb. of the best coal is generally required to heat

33.3 lbs. of water from 32° to 212°.

1 lb.....6.6 lbs. of water at 212° into steam.

and 1 lb.....5.5 lbs. of water at 32° into steam.

2 lbs. nearly.....one cubic foot of water from 32° to 212

11 lbs. nearly.....one cubic foot of water at 212° into steam.

13 lbs. nearly.....one cubic foot of water at 32° into steam.

Now, as a gallon contains ten pounds of water, it follows that

1 lb. of coal will raise $3\frac{1}{3}$ gallons of water from 32° to the boiling point.

5 lbs. of coal will convert $3\frac{1}{3}$ gallons of water at 212° into steam.

6 lbs. of coal will convert $3\frac{1}{3}$ gallons of water at 32° into steam.

We have given these approximate numbers for practical use, in the application of steam to some of the ordinary purposes and processes of art and domestic use, upon which we are about to enter; and they are such as may, with very ordinary care, be safely calculated on. But for a full exposition of the processes, and principles, and mechanical arrangements connected with the best methods of generating steam from fuel, we must refer to the article "STEAM-ENGINE," where the generation and condensation of steam find their most important uses.

It may perhaps be proper to remark, that a boiler, which is there called a boiler of one, two, or three horses' power, is one which is capable of raising one, two, or three cubic feet of water into steam in an hour. Whatever, therefore, be the application for which steam is wanted, if twenty cubic feet of water per hour are required to be converted into steam, a twenty horse-power boiler is that

Density of
Steam.

Dr Dalton's Table of the Density of Air and Steam.

Density of
Steam.

100 cubical inches of air under 30 in Barom. and 60° Fahrenheit, being 31 grs.											
Tempe- rature.	Vol. Air. under 30 in.	Weight of 100 cubic inches of steam.	Elasticity of steam.	Tempe- rature.	Vol. Air. under 30 in.	Weight of 100 cubic inches of steam.	Elasticity of steam.	Tempe- rature.	Vol. Air. under 30 in.	Weight of 100 cubic inches of steam.	Elasticity of steam.
Fahr.				Fahr.				Fahr.			
32°	480	.178 grs.	0.26	48°	496	.303 grs.	0.46	64°	512	.468	0.73
34	482	.191	0.28	50	498	.323	0.49	66	514	.492	0.77
36	484	.203	0.30	52	500	.341	0.52	68	516	.521	0.82
38	486	.206	0.32	54	502	.366	0.56	70	518	.551	0.87
40	488	.229	0.34	56	504	.384	0.59	72	520	.580	0.92
42	490	.245	0.37	58	506	.402	0.62	74	522	.610	0.97
44	492	.267	0.40	60	508	.420	0.65	76	524	.645	1.03
46	494	.284	0.43	62	510	.444	0.69	78	526	.680	1.09
								80	528	.721	1.16

Gay Lussac's Table of the Density and Volume of Steam.

Water at 32° being the unit of Density and Volume.											
Temp.	Density.	Volume	Temperat.	Density	Vol.	Temperat.	Density.	Vol.	Temperat.	Density	Volume.
Fahr. cent.			Fahr. cent.			Fahr. cent.			Fahr. cent.		
32.° 0°	0.00000540	182323	89.6° 32°	0.00003263	30650	147.2° 64°	0.00015010	6662	204.8° 96°	0.00051613	1938
35.6 2	609	164332	93.2 34	3619	27636	150.8 66	16356	6114	208.4 98	55191	1812
39.2 4	686	145886	96.8 36	4017	24897	154.4 68	17797	5619	212. 100	58955	1696
42.8 6	772	129587	100.4 38	4442	22513	158. 70	19355	5167	250.5 121.4	0.0011147	897.09
46.4 8	869	115305	104. 40	4916	20343	161.6 72	21013	4759	275 2 135.1	16150	619.19
50.0 10	974	102670	107.6 42	5418	18659	165.2 74	22794	4387	293.7 145.4	20997	476.26
53.6 12	0.00001092	91564	111.2 44	6023	16805	168.8 76	24702	4048	307.54 153.8	25763	388.16
57.2 14	1224	81686	114.8 46	6585	15185	172.4 78	26739	3741	320.3 160.2	30402	328.93
60.8 16	1372	72913	118.4 48	7242	13809	176. 80	28889	3462	331.9 166.5	34911	286.12
64.4 18	1534	65201	122. 50	7970	12546	179.6 82	31195	3206	341.7 172.1	39434	253.59
68. 20	1718	53224	125.6 52	8753	11424	183.2 84	33637	2973	358.8 181.6	48226	207.36
71.6 22	1914	52260	129.2 54	9606	10410	186.8 86	36237	2760	418.4 214.7	89863	111.28
75.2 24	2133	46877	132.8 56	0.00010525	9501	190.4 88	38984	2565	457.1 236.2	0.0129030	77.50
78.8 26	2376	42084	136.4 58	11523	8680	194. 90	41891	2387	478.6 265.9	203060	49.315
82.4 28	2643	37838	140. 60	12599	7937	197.6 92	44956	2224			
86. 30	2938	34041	143.6 62	13760	7267	201.2 94	48201	2075			

Steam. which must be procured for the purpose—and of course from 220 to 260 pounds of the best coal will be consumed in that time.

SECTION V.—THE APPLICATION OF OUR KNOWLEDGE OF THE PROPERTIES, PHENOMENA, AND LAWS OF STEAM, TO PRACTICAL AND ECONOMICAL PURPOSES.

Applica-
tion of
Steam.

1. Warming apartments and buildings by steam.
2. Heating greenhouses &c., by steam.
3. Evaporating solutions, drying fabrics, paper, gunpowder, grain, &c., by steam.
4. Warming baths, boiling liquids, and distilling by steam.
5. Preparation and economy of wholesome food by steam.
6. The steam-engine.

1. *Warming Apartments by Steam.*

Warming
by Steam.

66. One of the most important applications of steam in the economy of fuel, is its employment as a vehicle for transferring to a distance, and distributing uniformly, the heat of a fire for the purpose of warming an apartment or building. Its great efficiency for this purpose arises from the largeness of its capacity for caloric, because, as it holds a quantity of caloric equal to 1000 degrees, it will communicate as much heat as a mass of red hot iron; and it will have this advantage over the iron, that it can carry this heat to a distance without a similar loss; because, the heat being latent, will not be given out until it arrive at its destination and become condensed, when the whole of its 1000° will be usefully applied.

The manner in which warming by steam is to be effected, is this. At a convenient part of the building, and as low as possible, there is to be placed a close steam boiler of the ordinary construction. From this boiler a small steam pipe is to be carried to the part of the building which is to be warmed. This small pipe should be pretty thick, and carefully rolled round with a fillet of flannel to a quarter of an inch thick, and the boiler should be wholly covered with bricks and plastered over to keep it warm. This smaller steam pipe should have an area of one square inch for every six gallons of water that the boiler can boil off in an hour. Pipes of a larger size are to be laid round the room above the floor, or under the floor if apertures be left to allow a free circulation of warmed air to enter the room; but the best method we have seen is, to make the surbase, which passes round the room of thin iron plate or copper having the external figure of the surbase, and sufficiently strong to withstand the pressure of the steam, which strong tin plate or copper of $1\frac{1}{2}$ lb. to the foot will sufficiently effect, if the surbase be not more than about 4 inches square. Into these larger pipes the steam is to be conducted, and in them the steam will be condensed into water, and will give 1000° of heat to the colder air of the room which is in contact with the outside of these pipes. In doing so the steam being condensed into water, small pipes of lead or tin must be provided, for the purpose of bringing back this condensed water into the boiler; and, in order that they may act well, care is to be taken that a gentle slope, of about an inch in 20 feet, be given to all the pipes. The condensed water being thus conducted back to the bottom of the boiler, it will there be replenished with heat, and in the form of steam will again carry up its supply of 1000° to the apartment, again to be given off as formerly to the room, and then returning once more to the boiler, a continual circulation of the same particles of water, giving out in each circuit a quantity of heat equal to red hot iron, is uniformly and gently imparted to and diffused equally over the apartment. The pipe which brings the steam from the boiler may be called the feeding pipe, the pipes which give off the heat the radiating pipes, and the pipes which lead back the water to the boiler the return pipes. We have already given dimensions for the feed

pipe. The return pipes need not be more than $\frac{1}{12}$ of the diameter of the feed pipe, but an increase of size could do little harm, and may have the effect of preventing accidental obstruction: the boiler will require to have a pint of water added now and then to supply accidental waste; and a safety-valve on the boiler is indispensable. A self-regulating feeder, such as that mentioned in the article STEAM-ENGINE, among the apparatus of boilers, is also to be recommended where it can be readily attained. It is necessary, however, to give directions at greater length for the dimensions of the warming or radiating pipes, as it is upon their proper construction and arrangement that the efficiency of the apparatus entirely depends; and the apparatus has frequently failed from the want of proper precaution. The radiating pipes in the room are generally too small. It is their extent of surface, and the free circulation of air round them, which determines how much of the heat will be given out, and how rapidly. From very accurate experiments I am induced to conclude, that a room containing 500 cubic feet of air, and exposing 400 feet of surface, may be maintained at a temperature of 20° above that of the air without—that is to say, at 60° in the inside of the room when the atmosphere is at 40° without—for a space of twelve hours, by the evaporation of 2 gallons of water, and at the expense of about three pounds of coal of the value of one farthing. But this supposes that there is no ventilation, and that the air of the room is never changed; whereas, the presence of one individual would render it necessary to introduce nearly 400 cubic feet of external air every hour. Now, the heat of 20° given to 400 cubic feet of air would require the evaporation of 3 gallons of water; and, therefore, the evaporation of 3 gallons of water would be required for such a room, and 3 gallons for every person in it, if properly ventilated, and for every 2 gallons there should be at least one square foot of radiating surface; so that such a room, occupied by one person, would require a surface of warming pipe equal to $2\frac{1}{2}$ square feet, and so on for every such room and occupant, for a space of 12 hours in the day.

Thus, the evaporation of 1 gallon per day for every 400 feet of surface, with a difference of temperature of 20 from the external air, and $1\frac{1}{2}$ gallons per day for each person, and 1 square foot of radiating surface, is a standard from which we easily calculate.

A room 30 feet long, 20 feet wide, and 10 feet high, has a surface of 2200 feet, which would require $5\frac{1}{2}$ gallons; six people would require 9 gallons; therefore, 14 $\frac{1}{2}$ gallons of water and $7\frac{1}{4}$ feet of radiating surface will heat the well-ventilated room 12 hours for 6 persons at an expense of 25 lbs. of coal, or about threepence per day; or a whole house, occupied by 6 persons, may be warmed, if 30 feet high, 30 feet wide, and 30 feet deep, at tenpence a-day, the price of coals being twenty shillings a-ton.

It is scarcely necessary to add, that the radiating pipes may be best constructed of thin copper, and ought to be roughened and blackened on the outside.

In the same way the calculation may be made for any other room, building, and number of occupants.

For more extensive and minute information on the subject of Warming, the reader is requested to consult the article "WARMING AND VENTILATION," in the Encyclopedia.

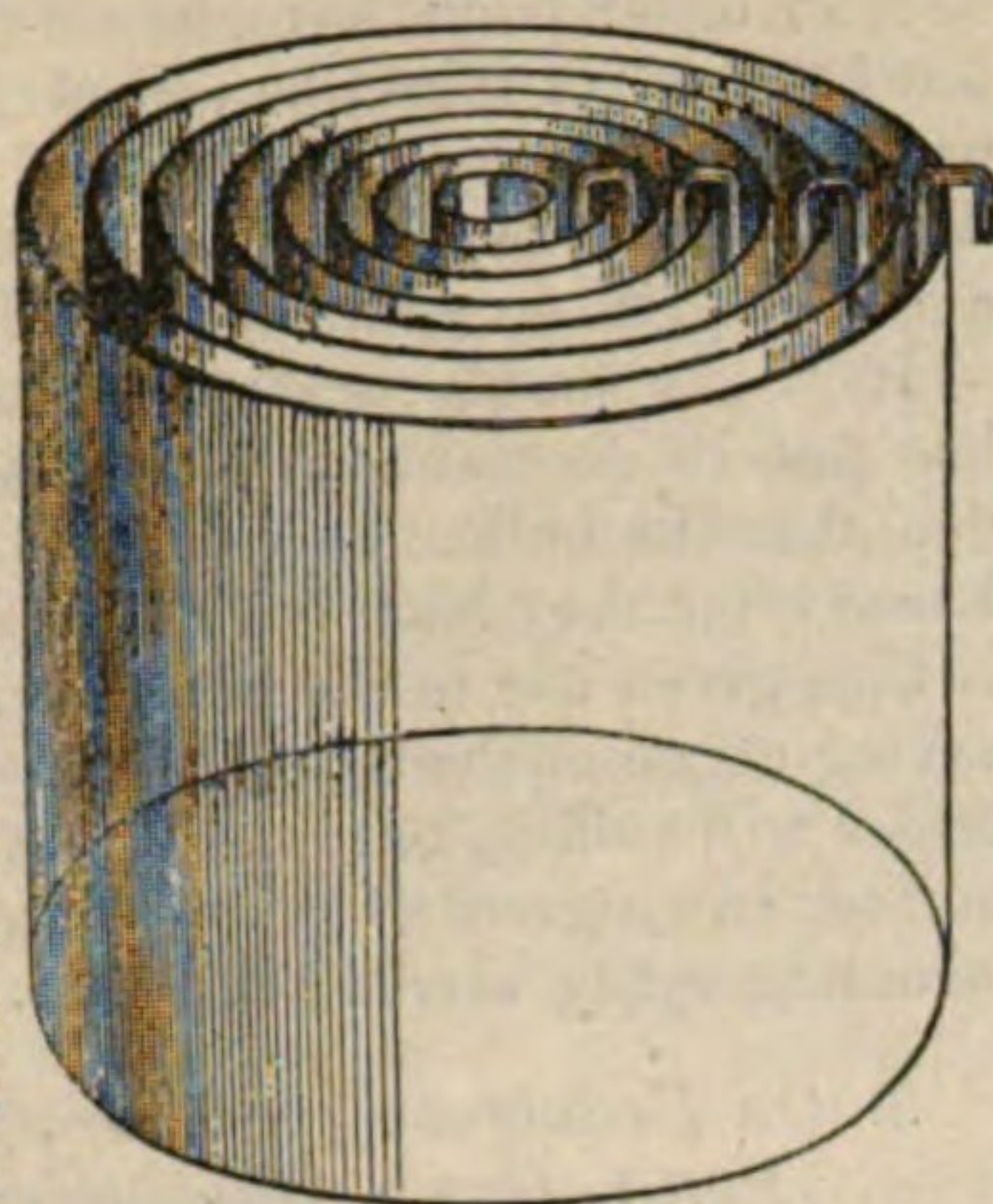
The form in which the radiating surface may be distributed admits of variety.

Provision must be made for the expansion and contraction of the pipes.

The arrangement of steam in the apartment to be heated is of some consequence. It is, we have already stated, sufficiently out of the way in the surbase, but, in that case, much heat passes out into the walls and wood. It may stand on the hearth like a stove, and consist

Steam. of concentric cylindric
Warming chests within each other
by Steam. (fig. 24), filled with
steam, and allowing air
to ascend by the sides
and through the inter-
vening spaces, so as to
be made warm, and
the outer surface radia-
ting directly on the sur-
face exposed. It may be
tubular, and coiled in
a large quantity in a
small box fitted up exter-
nally in the appearance
of a cabinet or pedestal
in the apartment, thus:

Fig. 24



(Figs. 25 and 26); the
feed pipe commencing
at the top of the coils,
and the return pipe pass-
ing off from the bot-
tom. As the conducting
power of tin is nearly
equal to that of iron,
a quantity of tin pipe
will suffice, and be more
economical than iron
or copper. This coil
may be placed in a cabi-
net or pedestal of the
form of Fig. 26, and
the warm air will have free egress through the wire
work of the panel.

Fig. 25.

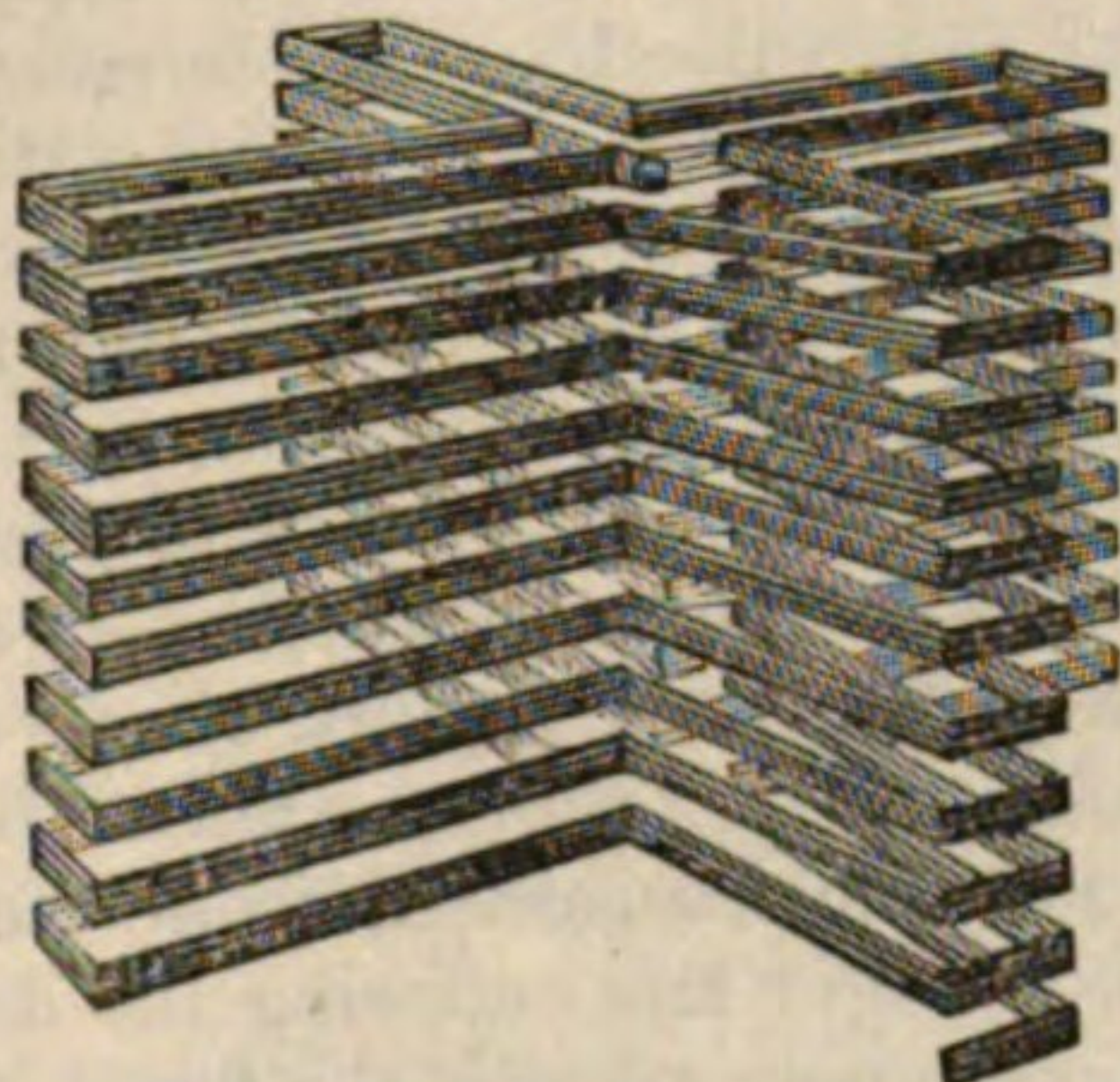
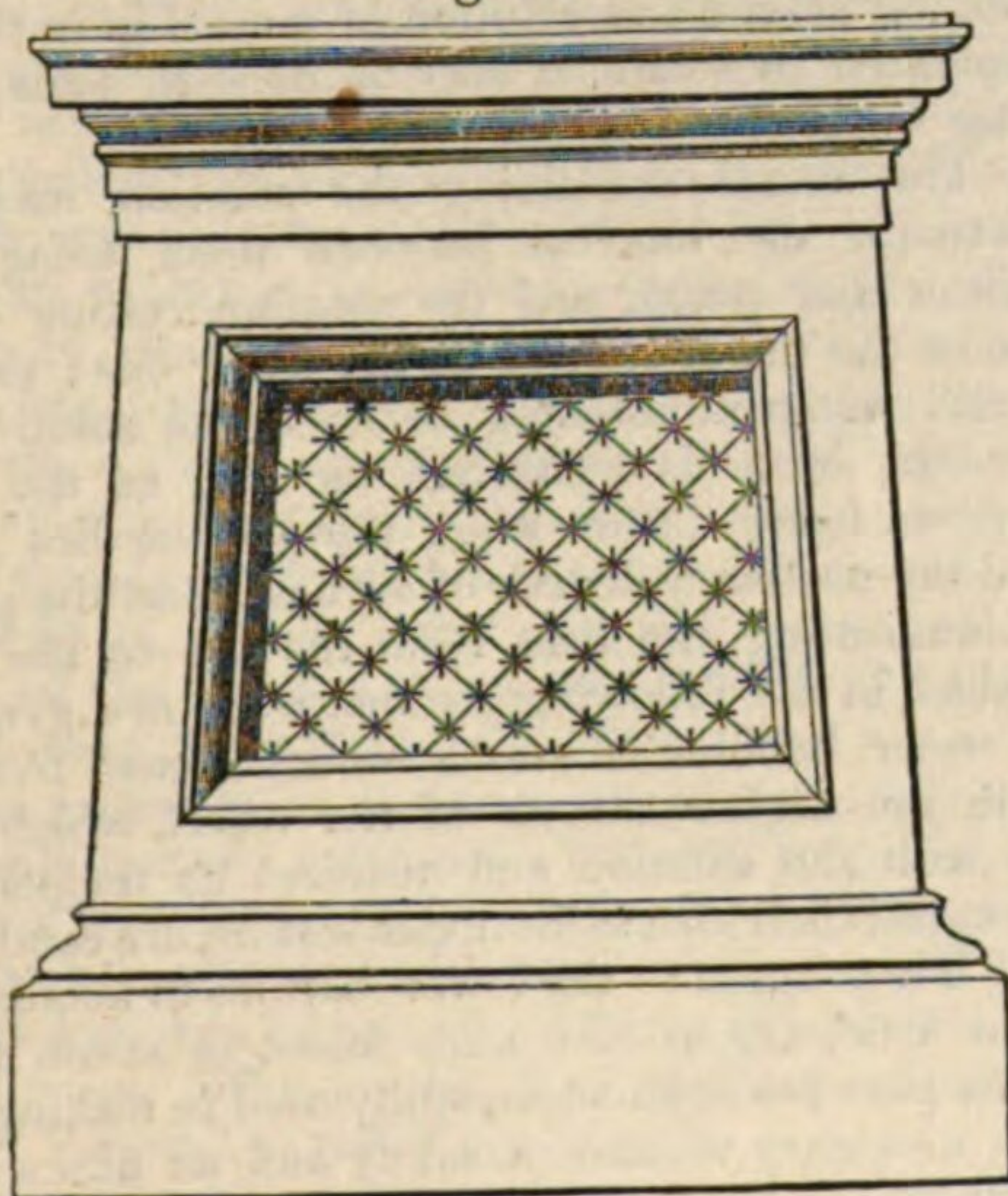


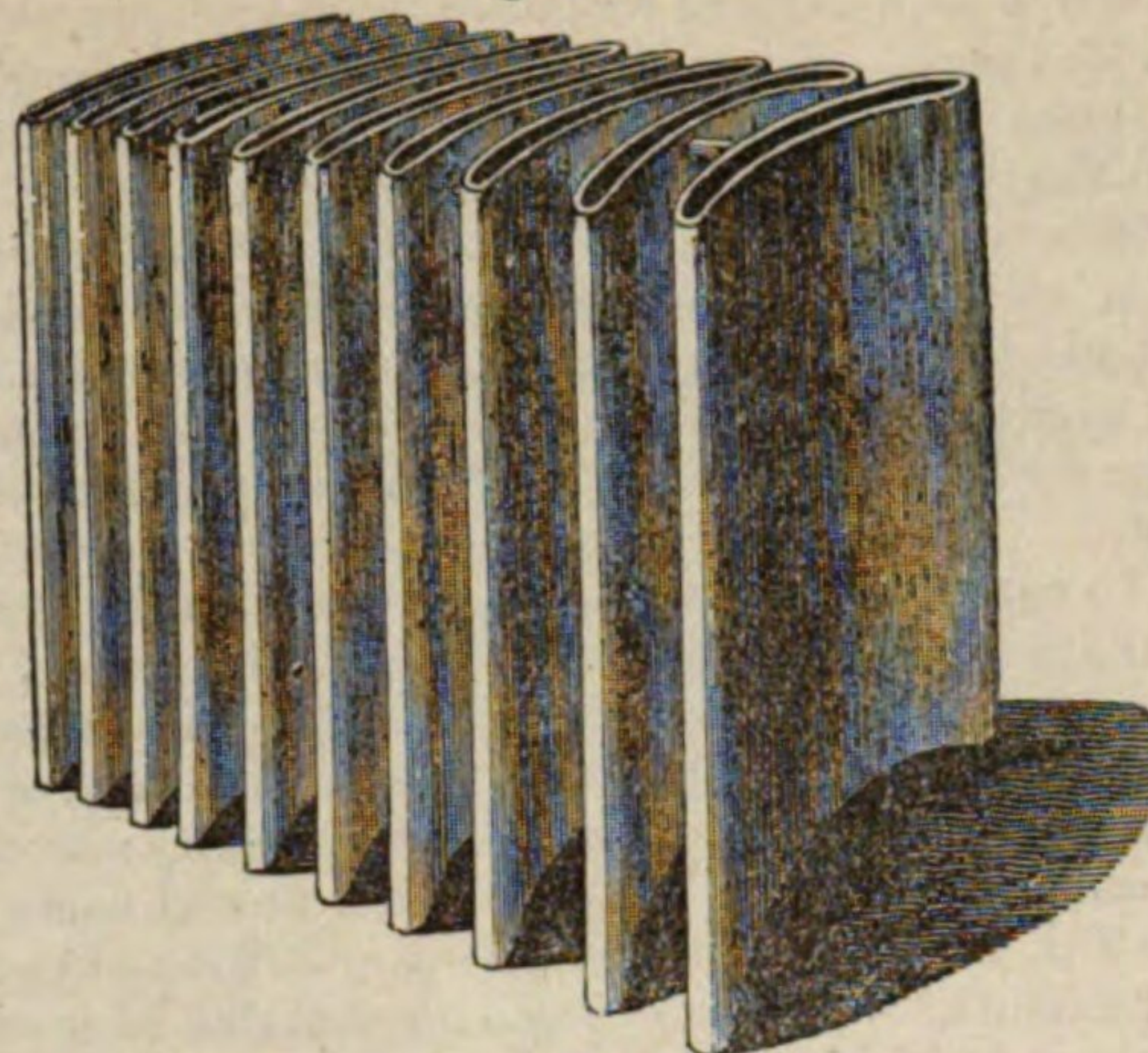
Fig. 26.



The next diagram (Fig. 27,) shows an arrangement of copper steam-vessels, by which an extensive surface is very efficiently exposed to the air, the condensed water being drawn off at the bottom.

There is one case in which warming by steam may be employed with especial advantage, and where it is frequently neglected—where the power of steam is already employed to drive machinery. Let the engine employed be what is called high-pressure, or non-condensing, in which the steam escapes from the engine and is passed off into the air; and, instead of the common plan, let the steam from the engine be conveyed in pipes through the apartments to be warmed, and let the diameter of the pipe

Fig. 27.



Steam.
Warming
by Steam.

gradually increase towards the end of its circuit, and finally terminate in a hot-water pipe, which may also circulate in the building and there will be given out the whole original heat of the steam after having done its work in the steam-engine, and that as effectually as if there had been no steam-engine at all, and the whole power of the engine will thus be clear saving. This will be the case to a still greater extent if the steam-engine work expansively, and may further be increased if the pipes be so formed as to constitute an aerial condenser. For further information on this subject see article STEAM-ENGINE.

2. Warming Hothouses, Greenhouses, &c. by Steam.

67. The principles which regulate this application of Green-steam are similar to those mentioned already in Art. 66, houses, &c. and steam possesses the same advantages in the distribu- warmed by tion of heat for this purpose, which it does in the cases Steam. already mentioned. The warmth thus distributed is freed from those risks of injury to the vitality of the plants, which accompany the old method of warming by hot air flues, in which a contaminated and unwholesomely dry air and unequable temperature were inevitably produced, and an occasional annoyance from smoke. The warmth given out by the steam is of uniform intensity throughout the whole length of the glass; it occupies very small space—one furnace and chimney is all that is required for any extent of range of glasshouses, as the steam may be conveyed to any usual distance in well swathed pipes without sensible loss. The saving thus effected by the concentra- tion of the fire, and by its equable distribution, has been found to produce an economy of more than one-third of the fuel commonly used. At Sion House, the seat of the Duke of Northumberland, there are nearly a thousand feet in length of glasshouses heated by one such apparatus. The boiler and chimney may also be placed at a convenient distance from the houses—a circumstance which contri- butes much to the beauty of this arrangement.

Those who wish to study the details of this subject are referred to Mr Loudon's Horticultural Works, and to the article "HORTICULTURE," in this Encyclopedia. The fol- lowing are the mechanical principles and arrangements that belong exclusively to this article.

Our first subject of enquiry, is into the amount of heat requisite to sustain the glass at a given temperature higher than that of the external air; if we take the tem- perature of the atmosphere at 35°, and that of the hot- house at 65°, giving 30° of difference, we shall have a case approaching near to that of a glasshouse in winter. In order to determine this question, which can only be as- certained by experiment, the author has examined a case upon a large scale, which may furnish a standard of com- parison.

Steam.
Green-
houses, &c.
warmed by
Steam.

The large palm house of the Botanic Garden of Edinburgh is an octagonal structure, 60 feet in diameter, and 45 feet high. Excepting stone pillars at the angles, and between the windows, of about three feet wide, the whole building is glass, presenting a surface of almost exactly 5000 square feet of glass. The quantity of fuel required in a cold atmosphere, having a mean of 35°, is 1344 pounds for 24 hours; being at the rate of 269 lbs. of coal for every 1000 feet of glass in a day, or 11.2 pounds an hour for 1000 feet, or .0112 of a pound per hour for each foot.

To confirm this observation, it was thought proper to examine another house of different dimensions. The eastern wing of the great range of houses is warmed by a fire, which consumes half that quantity of coals, of about half the value, being dross of a bad quality; so that its consumption is about $\frac{1}{4}$ of the other in real value, being about 672 lbs. of dross, equivalent to 336 lbs. of good coal in 24 hours. Now, the exposed glass of this wing amounts to about 1376 square feet, being at the rate of 243 lbs. to 1000 feet—a result which is sufficiently near to the other, to allow us to assume 250 or 260 lbs. of fuel in 24 hours for each thousand feet, as a standard of tolerable accuracy in such cases. It may be useful to add, that these houses are in tolerably sheltered situations, and that the glass faces in every direction, so as to be acted on with tolerably uniformity.

Hence we have the following results:

Temperature of the air 35°—temperature of the hot-house 65°.

Heat sustained 24 hours, by 250 lbs. of good coal, for 1000 square feet of glass.

Heat sustained 1 hour, by 10.4 lbs. of good coal for 1000 feet of glass.

Heat sustained 1 hour, by 0.0104 lbs. of good coal, for one foot of glass.

To find what amount of steam will be required to warm such a house, we have only to apply the calculations of Art. 66; 10.4 lbs. of good coal will convert seven gallons of water into steam; therefore, a boiler of one horse's power is necessary to evaporate a sufficient quantity of water for the supply of steam for each 1000 feet of glass; that is to say, for the palm-house alone, a boiler of five horses' power would be required to furnish steam; and this supposes the hot water of the condensed steam to be returned into the boiler immediately; and if this were not the case, six horses' power would be the size of boiler ordered for this purpose: hence—

To warm a hothouse by steam, there is required the boiler of a steam-engine, reckoned at one horse's power for every thousand feet of glass.

The method of distributing the heat through the rooms of the hothouse, is not a matter of so nice calculation as in a common apartment. There is much greater convenience for this purpose in a greenhouse than a common room, on account of the necessary vacuities under the ranges and beds. In general, a single circuit of steam-pipe four inches in diameter, round the apartment, with a return pipe of equal dimensions laid parallel to it, is sufficient.

It is, however, of great importance to provide a remedy for one of the practical inconveniences of steam. When the fire is not very carefully tended, as during the night, the steam in the boiler falls below the proper point, and the supply instantly ceases. This is remedied by the following method. Cast iron boxes, a foot square and five or six feet deep, are filled with stones, and ranged round the forcing rooms—a pipe passing into each of them communicates a supply of steam to them, and the stones they contain. The caloric entering first of all with rapidity into the stones, is afterwards given out gradually by them to the house; and the advantage of this arrangement is, that even if neglect or accident were to occasion a tem-

porary cessation of the supply, this heat would still continue to be given out from the matter of the boxes for several hours until the defect might be remedied. These boxes of stones perform the same function for caloric that a fly-wheel does for mechanical power—absorbing it when in excess, and giving it out again when deficient.

It is a valuable hint to economy, which Mr Macnab has put in execution in his houses at the Botanical Garden, that the boiler flues should be extended to the greenhouse after they have left the boiler; the remaining heat is thus given out to the hothouse, and the last degree of saving accomplished. With this arrangement a smaller boiler will suffice, but it will not always be convenient; neither can a greater length than about 30 feet of flue be advantageously used in this way.

3. On Evaporating and Drying Solutions, Cloths, Paper, Grain, Gunpowder, &c., by Steam.

68. We have already observed how well the peculiarities of steam enables us to make use of it as a vehicle for the collection, transference, and distribution of heat. In addition to the facility with which it may be carried to a distance, and the uniformity of temperature resulting from it, we have this further adaptation to the purposes now under consideration, that the temperature can at no time become so great as to produce injury, or deteriorate the substances to which it is applied. Hence it follows that thickened liquids, strong solutions, and any porous solid matter impregnated with fluid may be evaporated, and wholly separated from the fluid, without incurring the danger and suffering the deterioration resulting from direct application of the fire. And, further, by the proper application of steam, as a conductor of heat, liquids may be warmed, evaporated, and even boiled in vessels of wood, which is in some cases, as in brewing and delicate distributions, a matter of much importance.

When any mixture or solution of a solid in water is to be evaporated by steam, it may be done in some of the following ways.

(1.) The vessel containing the solution may have two bottoms, the interval between them being filled with water and steam, and the solution resting on the upper one, the fire is applied to the under one; thus the steam and water intervening between the solution and the fire, the latter is protected, as well as the vessel itself, from being burnt when the process has nearly attained the necessary degree of dryness; and the process of communicating the heat from the fire to the water takes place in the following manner; the fire generates in the water bubbles of steam, which ascend from the lower to the higher bottom of the vessel, which is in contact with the solution and acquires its temperature, and, giving off their heat to the upper bottom, are condensed, and fall down again to the lower bottom to acquire the accession necessary to rise, once more, in steam to the top. This plan has been successfully used in making salt; and it is necessary to have a safety and an atmospheric valve attached to the space between the lower and upper bottoms. The quantity of heat required for the purpose of evaporating the water of the mixture is neither increased sensibly, nor diminished by the intervention of the steam between the bottoms; the number of gallons of water to be evaporated from the solution will determine the quantity of heat by Art. 66.

(2.) A second method of producing evaporation is to introduce among the mixture a steam pipe, so as to wind amongst it either in the form of a helix, like a cork-screw or worm of a still, or to perform such a circuit as shall expose a large quantity of surface, with tolerable uniformity, to the fluid for the absorption of heat from the steam. Copper is the best material for the tubes, and wooden tanks lined with lead or tin will contain the mixture. The fuel

Steam.
Green-
houses, &c.
warmed by
Steam.

Evaporat-
ing by
Steam.

S T E A M.

Steam. required for evaporation will be 5 lbs. for every 3½ gallons of water to be evaporated, and the steam boiler must have one horse's power for every 6 gallons to be evaporated in an hour.

Evaporating by Steam. (3.) A third method is the invention of Mr Goodlet of Leith. The substance to be evaporated is forced by means of a pump into a long copper pipe, which enters a close steam boiler, and after winding through it so frequently as to expose a sufficient surface for a sufficient length of time to acquire the necessary supply of heat from the boiler, again passes out from the boiler and discharges its heated contents into an appropriate reservoir, again, if necessary, to be passed once more through the same process by the force pump. In this case the substance is brought to the steam boiler for evaporation instead of having the steam brought to it, and thus any loss of heat during the transit of the steam is prevented.

Steam Kilo. A steam kiln for drying grain has been used with great success by the same person. The grain is spread out on the iron floor of a large room—this floor is perforated with a multitude of small openings, or formed of a very fine grating; immediately under the floor steam pipes of 6 inches diameter lie parallel to each other at small intervals apart, and radiate heat directly to the floor and the grain, and also to the surrounding air, which in this hot state ascends through the grain; numerous large ventilators being provided for the escape of the vapour thus impregnated with moisture, after it has ascended through the grain. This method has been found effectual, and is attended with less risk of injury than the ordinary one.

Drying by Steam. In the processes of drying and printing cloths and fabrics of various kinds, rapid and complete drying is of much importance. This is effected principally in what is called a drying frame: this consists of a dozen of tin cylinders, a foot in diameter and 6 or 8 feet long; these cylinders are closed completely by two hemispherical ends, and are placed upon an axis in a frame, so as to revolve in contact with each other. Steam is conducted into all these cylinders by a pipe passing through the axis, which is hollow, and the joint is made steam-tight by a stuffing-box similar to that of the cover of a steam-engine cylinder. A piece of cloth dripping from the dye-vat is passed through the frame once and is then perfectly dry. Of course, the quantity of steam required for this process is proportional to the number of pounds of water to be evaporated from each piece, that is, to the difference between the weight of a piece when wet and when dry. The number of lbs. being ascertained, the fuel and power of the boiler are found from article 66.

In the manufacture of paper the process of drying by steam is beautifully exhibited. The wet pulp, laid out on the web of wire cloth, is gradually strained as it approaches the large hollow cylinders, around which it winds for half a minute and then comes off perfectly dry finished paper, ready for use. This process is minutely described in the article "PAPER" of this Encyclopedia.

4. *Warming Baths, Boiling Liquids, Distilling by Steam.*

Warming Baths by Steam. 69. To heat water rapidly, and in considerable quantity, by means of a fire placed at some distance, is a problem frequently proposed; and steam for such a case is an excellent vehicle for the heat. Let there be placed in a steam boiler 10 gallons of water, and heated into steam; these 10 gallons conveyed to a reservoir or bath of water at a distance, by a small lead pipe, will heat nearly 55 gallons of water from 32° to the boiling point, or 165 gallons from 40° to 100°, the usual temperature of a warm bath. A bath of the ordinary construction will require about 160 gallons, and the said 10 gallons will require 18 lbs.

of coal, value sixpence. Besides this, the sides of the bath, if made hollow, may be warmed by the introduction of steam between the lining and the outside, at the same time that the water is warmed; and the apartment may further be heated with steam pipes from the same apparatus.

The most effectual method of communicating the heat of steam to water is to pass the open end of the steam pipe from the boiler directly into the water to be heated, so as at once to mix with it. The mouth of the pipe, properly regulated by a stopcock, should enter at the bottom, and be directed from one end of the bath along one side towards the other, and thus the impetus of the steam on entering will communicate to the water a circulation highly conducive to an equable distribution of heat.

A very simple apparatus of this kind may be placed in the same apartment with the bath itself. A boiler 4 feet long and 2 feet deep, with a fire covering a square of 18 inches, will heat such a bath in three quarters of an hour. A copper boiler will be most effective, and the steam pipe should first be matted with bandages of flannel, and then stitched with canvass painted, from the boiler to where it enters the bath.

In establishments where there are many baths, a reservoir at the top of the building may be kept constantly filled with water ready to descend into the baths, the reservoir being supplied with heat from the steam pipe of a boiler placed in the outer buildings, or some other suitable place. It is to be recollected that the boiler used must be what is called a one, two, or three horse power boiler, according as one hundred, two hundred, or three hundred gallons per hour are wanted; and so on for every additional hundred gallons of water at 100° of temperature—one horse power of boiler for one hundred gallons.

Boiling Liquids by Steam. The same process may be used for heating and even for boiling a liquid or solution, in which no injury will result from adding the steam of this condensed water to the liquid. In a dye-work, or other work where much boiling and many solutions are used, steam boiling in this manner is a process of great convenience and value. The vessels containing dyes of various kinds, including leys and solutions of various substances, in which cloths, yarns, wools, and various materials are to be boiled, are ranged around a spacious apartment. Around this apartment, attached to the wall, circulates a steam pipe of two inches diameter, from which smaller branch pipes go off to each of the boilers from the nearest point, and pass down to the bottom of their respective vessels. The exit of the steam is governed by a stopcock under the hand of the operator; and by this means he can easily, by allowing a smaller or greater supply of steam to enter the liquid, produce a uniform and gentle simmer or excite an instantaneous and tumultuous ebullition. Two great advantages give this method much superiority over the common mode of boiling by the direct action of the fire. The condensed steam supplies to the solution exactly as much water as is lost by evaporation, so that it remains of the same strength through a protracted process, and there is no injury sustained by allowing the substances immersed to settle down and rest at the bottom.

Where it is not allowable for the caloriferous steam to be condensed in contact with the liquid to be warmed or boiled, we must resort to the method of heating by surface; that is to say, the steam must be conveyed through the mass of liquid by a pipe, or other conductor best fitted to give out the heat or retain the water. A very thin pipe of the purest soft copper is best for this purpose; 2 inches in diameter and $\frac{1}{20}$ to $\frac{1}{40}$ of an inch in thickness will be found good dimensions, and a square foot of surface for every 10 gallons of water to be boiled per hour will be required. For some purposes, it will be enough to wind the pipe in a spiral

Steam. round the inside of the vessel to be heated; but if the vessel be large, numerous pipes must pass through the liquid. For boiling 1000 gallons per hour, 200 feet of copper pipe 2 inches in diameter are required.

Boiling Liquids by Steam. In distillation by steam, the same method of communicating heat to the liquid to be distilled is employed as already described in boiling. But the vapours of other liquids, having less specific caloric than water, a smaller quantity of steam from the boiler will be required to evaporate than to evaporate an equal quantity of water; thus the heat of one gallon of water will evaporate and cause to be distilled 2 gallons of alcohol, 3 of sulphuric ether, and 4 of turpentine. It is a curious phenomenon, of which distillers should avail themselves in carrying off the vapour in distillation, that although alcohol floats on water, and ether on alcohol, nevertheless the vapour of water floats above vapour of alcohol, and vapour of alcohol above vapour of ether.

The densities of water, alcohol, and ether			
being	10.	8.	7.
and the densities			
of their vapours	6.	16.	25.
in round numbers.			

5. Preparation of Food by Steam.

Cooking by Steam. 70. The last of the applications of steam which we shall here examine is that which was historically the first, its application to cooking and other domestic uses. This invention makes its appearance in the following record of the Royal Society of London.

At a meeting of the Council of the Royal Society,
December 8, 1680.

Papin's Digester. Ordered, that a book intituled *A New Digester, or Engine for softening Bones, &c.*, written by Denys Papin, Doctor of Physick, and Fellow of this Society, be printed and published.

CHR. WREN.
This work on the New Digester was accordingly published in 1681; "Containing the description of its make and use in these particulars, viz., Cookery, Voyages at Sea, Confectionary, Making of Drinks, Chymistry and Dyeing, with an Account of the Price a good big Engine will cost, and of the profit it will afford."

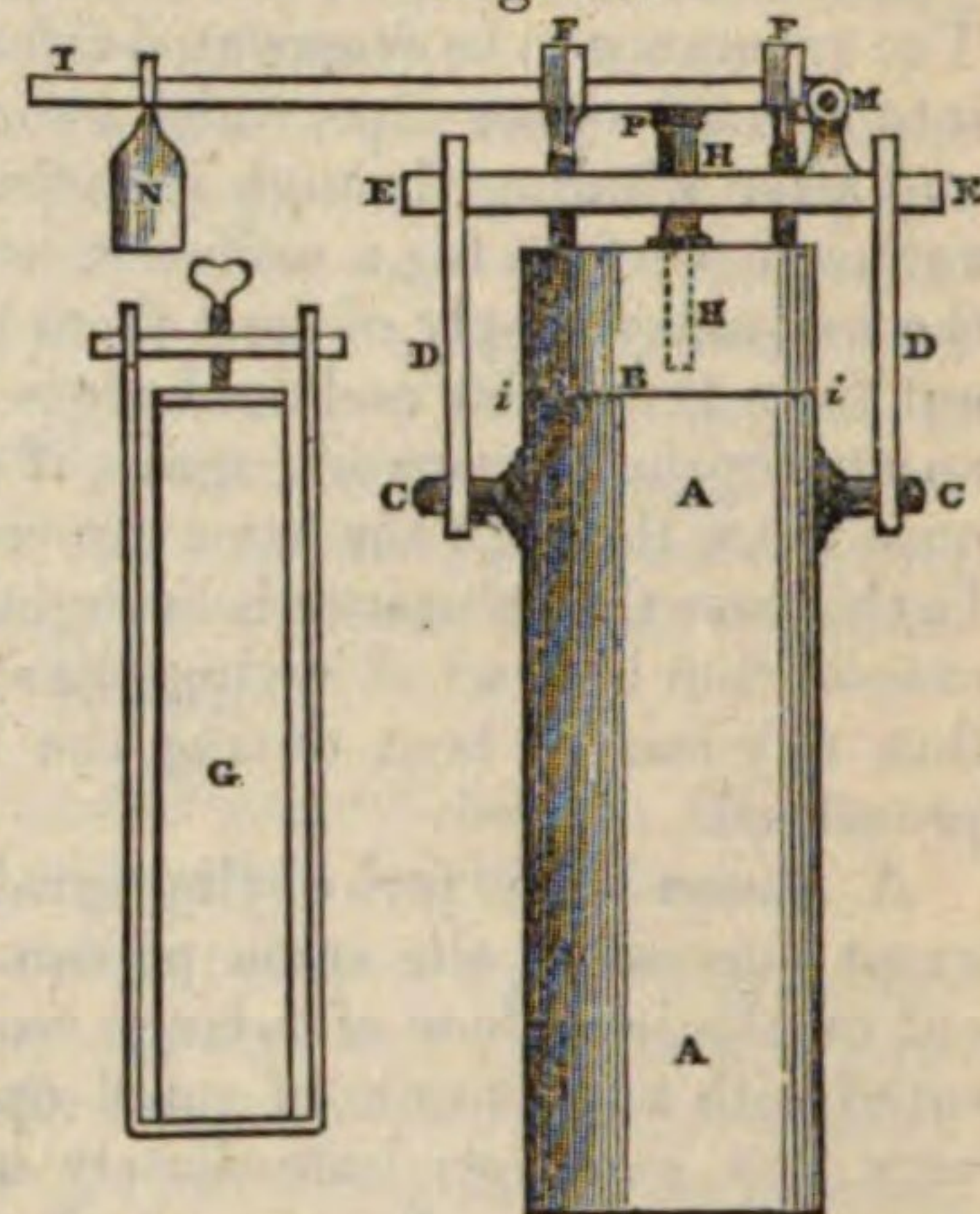
The following list will show the extent to which the learned doctor had proceeded in applying steam to the improvement of the dietetic art. It is copied from the Index to the work. "(1.) How to know the quantity of pressure in the Digester. (2.) How to know the degree of heat. (3.) How meat may be kept upon the fire three times as long as is necessary to make it ready, and yet it will not be spoiled. (4.) The same experiment made upon bones. (5.) How to boil mutton. (6.) How to boil beef. (7.) How to boil lamb. (8.) How to boil rabbits. (9.) How to boil pigeons. (10.) How to boil fish. (11.) How to boil pulse. (12.) How to make jelly, very cheap. (13.) Glue for glasses. (14.) Harts-horn turned like Parmesan cheese. (15.) A mackerel kept without salt. (16.) Salt water as good for nourishment as fresh water. (17.) To make sweetmeats at a cheap rate, and of a new taste. (18.) To make two sorts of drink with the same fruit. (19.) To make a new sort of wine. (20.) Tinctures drawn in the hundredth part of the time usually required for them. (21.) New ways for distilling. (22.) How to hatch chickens. (23.) How to save the labour of grinding cochennille. (24.) To dye with thick juices. (25.) To make horn and tortoiseshell soft for a great while."

This catalogue of uses of steam we shall shortly run over, as the modern uses of steam for cookery are principally applications of Dr Papin's methods, and as valuable economization in the preparation of food on a large scale has resulted from them, especially in the extraction of

highly nutritious food from bones. A digester on the principle of Dr Papin is used in every modern kitchen. Steam.

"Description of the Digester and how to use it safely." Cooking by Steam.

Fig. 28.



"A A is a brass (or copper) cylinder, hollow within, shut at the bottom and open at the top. B is another cylinder inverted upon it. C C are two appendices or ears cast to the cylinder A A, as the trunnions of a piece of ordnance. D D are two pieces of iron put upon the appendices at one end, and the iron bar E E at the other. F F are two screws, which serve to press both the cylinders A A, B B, against one another. G is another hollow cylinder, made of glass, pewter, or some other materials, fitted to receive those things that are to be included in the cylinders A A, and B B, with water all round it.

"To use this engine with convenience and ease, it ought to be fitted in a furnace built on purpose for it, and should go on as far as the appendices C C; so the fire being underneath, and the screws well fastened, and a piece of moistened paper laid between the cylinders at the joint *ii* to make it steam tight, you may boil your meat as long as you please without danger of wasting it by the exhalation of the volatile parts.

"To know the quantity of the inward pressure, you must have a little pipe open at both ends as H H: this being soldered to a hole in the cover B B, is to be stopped at the top with a little valve P, exactly ground to it. This must be kept down with an iron rod I M, one end of which must be put into an iron staple M, fastened to the bar E E, and the other end kept down by a weight N to be hung upon it nearer or further from the valve according as you would keep it less or more strong, after the manner of an ordinary Roman balance, or steelyard.

"To know the degree of heat, I hang a weight to a thread about 3 feet long, and I let fall a drop of water into a little cavity made for that purpose at the top of it, and I tell how many times the hanging weight will move to and fro before the drop of water is quite evaporated.

"*Experiment.* Having filled my pot with a piece of a breast of mutton, and weighed five ounces of coals, I lighted my fire, and by blowing gave such a heat that a drop of water would evaporate in 4 seconds, the inward pressure being about 10 times stronger than the atmosphere: I let the fire go out of itself, and then the mutton was very well done, *the bones soft* and the juice a strong jelly. So that, having had occasion to boil mutton several times since, I have always observed the same rule, and never have missed to have it in the same condition, which I take to be best of all."

Beef required 7 ounces of coal and the same heat, and the beef was very well boiled, although there were more parts of the bones not quite softened. Lamb, rabbits, and pigeons, mackerel, pike, and eel, were subjected to the same process; whence the doctor infers that the bones of young beasts require almost as much fire as those of old ones to be boiled, that rabbit bones are harder than those of mutton, that tough old rabbits may be made as good as tender young ones by this means, that pigeons may be best boiled with a heat that evaporates a drop of water in 5 seconds, that mackerel was

Steam.
Cooking
by Steam.

cooked with gooseberries in a digester, the fish being good and firm, and the bones so soft as not to be felt in eating; and he particularly recommends, as an excellent dish cooked in this manner, cod fish and green peas.

The most important of Papin's experiments are those on the extraction of gelatine from bones, as now done on a large scale in France and in this country, as also the manufacture of essence of meat, soups, &c., especially suitable for long sea voyages.

"I took," says he, "beef bones that had never been boiled, but kept dry a long time, and of the hardest part of the leg; these being put into a little glass pot with water, I included in the engine, together with another little glass pot full with bones and water too, but in this the bones were ribs and had been boiled already. Having prest the fire till the drop of water would dry away in three seconds, and ten pressures, I took off the fire; and the vessels being cooled, I found very good jelly in both my pots; but that which had been made out of ribs had a kind of a reddish colour, which I believe might proceed from the medullary part, the other jelly was without colour like hartshorn jelly; and I may say, that having seasoned it with sugar and juice of lemon, I did eat it with as much pleasure, and found it as stomachical, as if it had been jelly of hartshorn. Mutton bones are better than beef bones; and he infers (1.) that one pound of beef bones afford about two lbs. of jelly; (2.) that it is the cement (gelatine) that unites the parts of the bones, which is dissolved in the water to make it a jelly, since after that, the bones remain brittle; (3.) that few glutinous parts are sufficient to congeal much water, for I found that when the jelly was dried, I had very little glue[-ten?] remaining; (4.) I used it to glue a broken glass, which did since that time hold very well, and can be washed as well as if it had never been broken; (5.) it is heavier than water, and sinks to the bottom; (6.) hartshorn produces five times its weight of jelly.

"From all these experiments, I think it very likely, that if people would be persuaded to lay by bones, gristles, tendons, feet, and other parts of animals that are solid enough to be kept without salt, whereof people throw away more than would be necessary to supply all the ships that England hath at sea, the ships might always be furnished with better and cheaper victuals than they used to have. And I may say, that such victuals would take up less room too, because they have a great deal more nourishment in them in proportion to their weight. They would also be more wholesome than salt meat. Vegetables, such as dried peas, may also be cooked by the steam of salt water without becoming salt."

We have entered thus fully upon the work of Doctor Denys Papin, and the properties of his digester for cooking, and extracting jellies by high-pressure steam, because it contains nearly all that is at present practised in the preparation of food by steam.

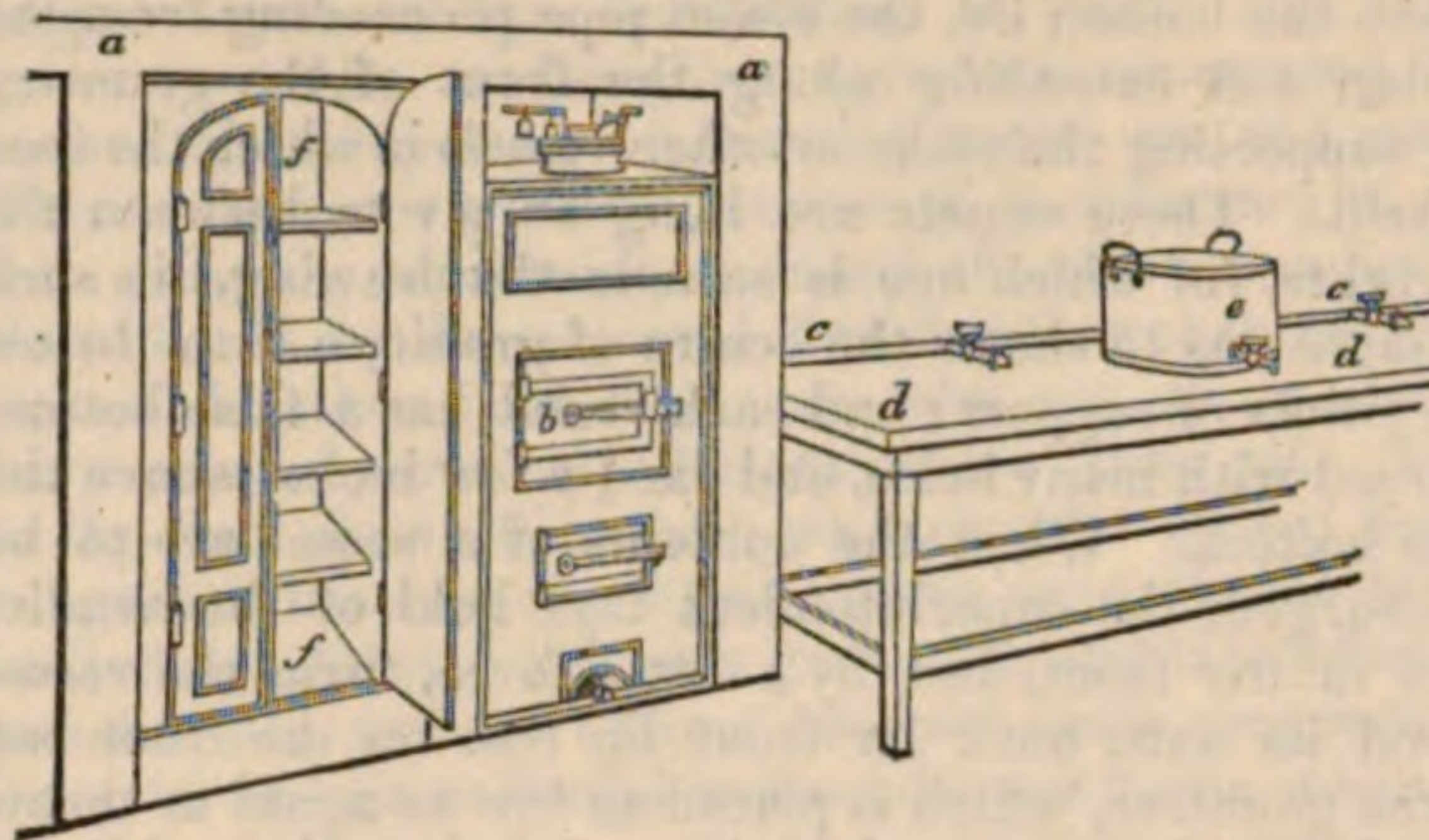
If to what has been already stated, we add, that if the steam of salt water be collected in a vessel kept cold on the outside, the condensed water will not be impregnated with salt, and may be used as food, the importance of steam in the economical and menial capacity of cook, will be sufficiently apparent. The supply of water to the crew of a steam vessel may be obtained in this manner, and an apparatus for thus procuring fresh water from the condensation of steam from salt water, has been used with advantage in ordinary ships.

Fig. 29 contains the steam-cooking apparatus used in modern kitchens; *a a* is a portion of the kitchen fireplace. In one of the divisions of it, *b*, is placed a steam boiler, furnished with the usual apparatus of feeding pipes, gauge cocks, &c. From this boiler a steam pipe, *c c*, is led along the back of the cooking table *d d*, and at certain

intervals, branch pipes, furnished each with a stopcock, project across the table at right angles to the main pipe.

Steam.
Cooking
by Steam.

Fig. 29.

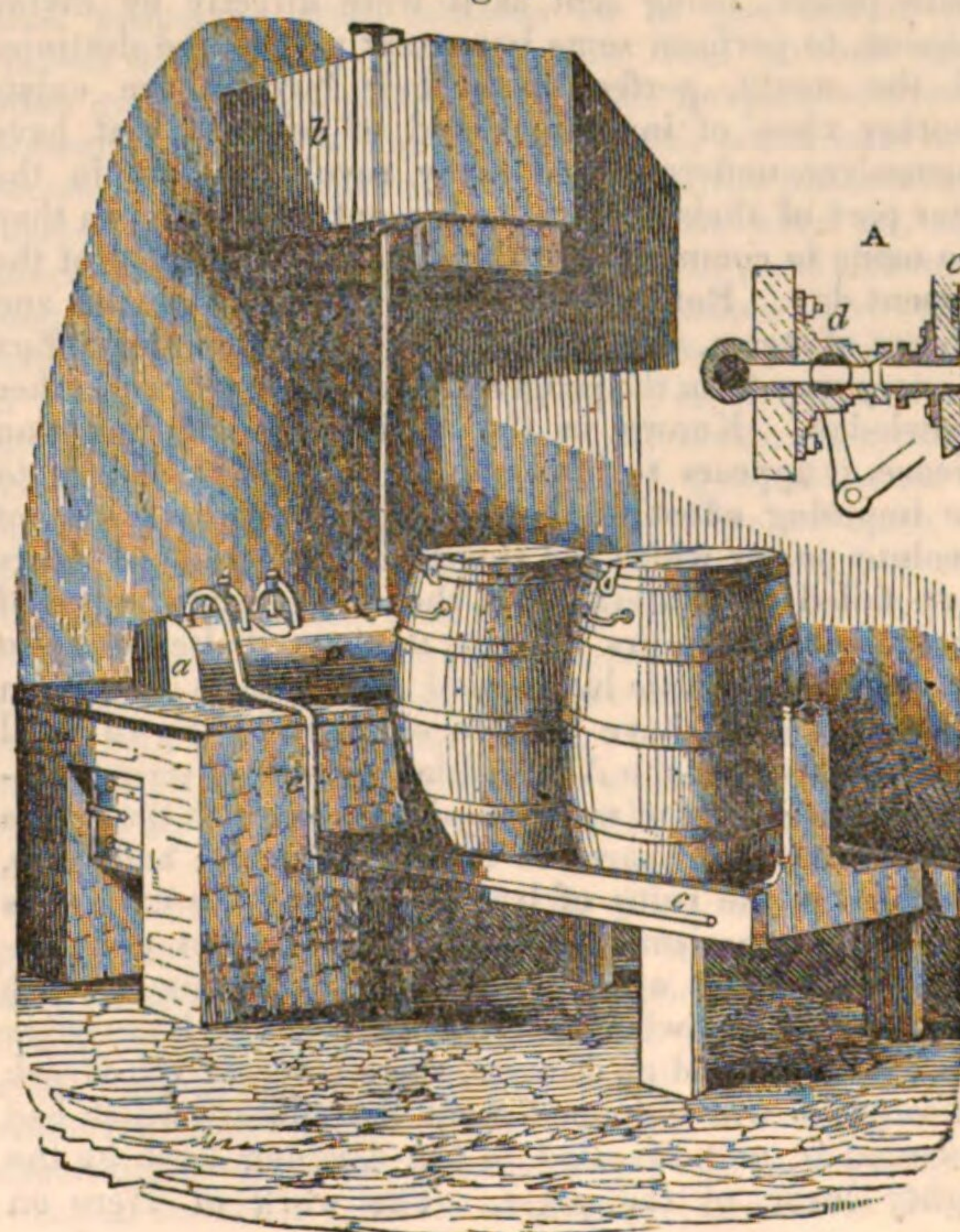


The extremities of these branch pipes are conical, and made accurately to fit into conical sockets inserted into the cooking pans, one of which, *e*, is seen in its place on the table. These pans have each a double bottom, the lower one close, the upper one perforated; between the bottoms the socket before mentioned, through which the steam enters, is inserted. The manner of using this apparatus is simple. The article to be cooked is laid in its place on the perforated bottom of the pan, the lid is applied, and the pan is joined to one or other of the branch pipes, by its socket receiving the conical end of the pipe; the stopcock is now turned, and the matter in the pan is subjected to the action of the steam. Each pan has a crane in front, to allow of the condensed steam being drawn off.

The remaining part of the apparatus is the hot closet, *f f*. This consists of a steam-tight iron box, containing shelves, inserted in another iron box of dimensions so much greater as to allow of a considerable vacuity being between them; into this vacuity the steam from the boiler is permitted to flow, and give out its heat to the articles placed in the closet to receive it.

Fig. 30 contains a steam-apparatus for cooking the

Fig. 30.



Steam. food of cattle and horses, designed by Mr Newlands of Edinburgh. *a a* is a steam boiler, furnished with man-hole, safety-valve, gauge-cocks, supply pipe, and regulating float; *b*, water cistern, placed not less than six feet above the boiler; *c c*, the steam pipe proceeding from the boiler, and extending along the front of the gauntree for supporting the casks or other vessels in which the food is held. These vessels are hung on pivots, between the uprights, (of which one is seen in the drawing,) in such a manner as to throw the centre of gravity a little below the points of support; and each vessel has a false bottom pierced with many holes, and fixed a few inches above the true bottom. When the contents of a vessel are to be discharged, the superintendent lays hold of the handle, seen in the front, and, by a little force, turns the vessel round its axis, until its front lip rest on the front bar of the gauntree, which is placed so low as again to throw the centre of gravity of the vessel below the points of support; the contents may then be emptied into a close barrow, or other suitable vessel, or into a trough extending along the front of the gauntree.

The manner of connecting the vessels with the steam-

pipe remains to be noticed. From the main pipe *c*, branches are carried through the front bar of the framing opposite to the centre of every vessel, of which there may be many, although two only are represented. Fig. A exhibits a section of the main pipe, the branch pipe, and a part of the bottom of the vessel. The branch pipe *d* terminates in a conical socket, and into this the plug fixed on the vessel *c* is fitted. When the vessel is in a vertical position, the connexion between it and the boiler is complete, but when, in being emptied, the vessel is overturned, the plug is withdrawn from the socket, and the communication cut off. When the vessel is again restored to its vertical position, the parts again fit each other without trouble or care on the part of the attendant. The branch pipe is moreover furnished with a stop-cock, the handle of which is wrought by a rod from either an eccentric or a crank fixed to one of the pivots of the vessel. When the vessel is overturned and the plug withdrawn, the eccentric shuts the stop-cock, and prevents the steam from escaping, and re-opens it when the vessel regains its vertical position.

(C. A.)

THE STEAM-ENGINE.

Steam-Engine.

It is a singular peculiarity in the history of the steam-engine, that, ever since the period which exhibits the earliest traces of its embryo, it has continued slowly and gradually to advance with the flow of time towards its present state of high maturity, though not yet, perhaps, of ultimate perfection. Other arts and inventions, once well known and successfully used, after having attained a certain measure of perfection, have again been lost sight of amid the ruins of empires and the revolutions of nations, never more to be rescued from oblivion. While some of these, on the one hand, have sprung suddenly up into maturity, arrayed in the panoply of immediate power, being sent as it were directly by divine mission, to perform some important part in the destinies of the world, perfect from their birth, there exists another class of inventions and of sciences that have themselves undergone so many revolutions as, in the later part of their history, to present nothing more than the name in common with the maturer knowledge of the present day. But our knowledge of the properties and powers of steam, and its agency by a steam-engine, differs in every way from the progression of other arts and other knowledge. Known in the earlier ages of Egyptian science, it appears to have played its part in adding to the imposing effect of those stupendous monuments of absolute power which the storms of thousands of years have failed to obliterate. In the more refined ages of Greece, steam appears to have ministered alternately to the elegance of Attic luxury and the delusions of heathen idolatry; and to have become extensively known until the destruction of the Alexandrian schools of science dispersed those seeds of mechanical science which the flames of its library have spared to Western Europe; and there, imbedded in the ruins of learning during the dark ages of second barbarism, they lay preserved, but unfruitful, among the other remains of the learning of the middle ages; and when at length the light of knowledge once more dawned on Europe, the science of the Greek philosophers was exhumed from the rubbish which had concealed it, and revealed to the dawning light by the mighty lever of the press. The work of Hero on

Pneumatics and Steam Machinery was one of the finest and earliest specimens of the art of printing. Since that time the science of steam, and the art of constructing the steam-engine, have made slow, regular, and progressive advancement, until this mighty work of many hands has at last attained a prominent importance in the interests of humanity, and become a mighty element in the future destinies of the world. In this remarkable course there has been no retrogradation. Centuries have added their contributions to the elucidation of its principles and the perfection of its mechanism; but no great revolution has ever thrown back, nor any single effort reproduced the mighty machine.

It is this peculiarity which has induced us to present to our readers the history of the steam-engine as the most apt and useful introduction to the perfect comprehension of its principles and structure. In many other subjects the history of the science or art is little more than an interesting and curious antiquarian research, fascinating to the virtuoso, and even instructive to the historian or philosopher, but by no means necessary, or even conducive, in any degree, to the acquisition or comprehension of the modern condition of our knowledge. What, for instance, have the astronomical systems of the Chaldees or the Greeks to do with the Copernican system of modern astronomy? In what degree would a learner be assisted in comprehending the sublime doctrines of the celestial mechanics of Newton, by having made himself thoroughly acquainted with the cycles of Hipparchus and Ptolemy, the crystal spheres of Frascatorius, or the multitudinous epicycles of Purbach? But with our knowledge of the phenomena and the powers of steam, the case has been widely different. The progress of the steam-engine has been co-ordinate with the progress of the human mind in physical truth. The history of the past improvements of the steam-engine is therefore the history of the human mind; and the same phases which have been severally presented, at widely separated epochs, by successive inventors, are the very phases of gradually growing knowledge by which a single individual mind does most naturally and most profitably proceed, step by step, to the

Steam-Engine.

Steam-
Engine.

full blaze of light which is thrown upon this subject by the illumination of modern science. Of so large a subject, one part only can be studied at a time, and that succession of parts by which they enter into the mind in easiest transition is the very succession in which history presents them to us.

We shall therefore divide this subject into two parts; the first containing a description of the steam-engine, and the elucidation of its principles, in historical order; the second forming a description of the functions and parts of the modern steam-engine.

PART I.—HISTORICAL DESCRIPTION OF THE STEAM-ENGINE. 1. THE ERA OF THE ANCIENTS. 2. THE ERA OF WORCESTER. 3. THE ERA OF WATT.

1. *The Era of the Ancients.*

The knowledge which some of the ancients possessed of the constitution of steam is remarkably in accordance with the most recent modern conclusions on this species of matter. Steam is now known to be only one of the common airs or gases whose particles at one degree of heat and of pressure assume a liquid form, and at another temperature and pressure become solid ice.

The modern doctrine concerning matter may be thus stated; that matter is known to exist in four conditions—solid, liquid, aerial, and ethereal. Earth and stone are exemplars of solid matter; water and mercury of liquid matter; the atmosphere, and smoke, and steam, of aerial substances; caloric, light, and electricity, of ethereal matter. It is further the doctrine of modern physics that no kind of matter exclusively possesses one of these conditions as its distinguishing property, but that all may, in certain circumstances, assume different conditions. Stone is not essentially solid, for, by the action of heat, it may be melted under pressure; and iron or lead, though usually solid, may be presented in the liquid form; and the earths have likewise assumed the form of liquids when the contrivance of the chemist has succeeded in placing them in appropriate circumstances. Neither is water essentially a liquid, for, when frozen, it becomes a solid, with which we may construct houses, bridges, utensils, and even floating structures capable of navigating the ocean; and, on the other hand, it is sometimes reduced into the vaporous or aerial form, as when the water of a vessel, acted on by heat, is wholly dissipated and dispersed in an invisible form in air.

It is also to be observed, that the condition of a body may be changed by the agency of heat. Solid ice, solid mercury, or solid lead, by the addition of heat, are converted into liquids, or are melted; and form liquid ice, (called water,) liquid mercury, (called quicksilver,) and liquid lead, (which has no separate name.) If to the liquid thus produced from the solid we add a certain other portion of heat, that will separate its particles still further from each other, and the matter thus diffused over more extended space becomes reduced to the aerial condition of steam, of mercurial or lithargical gas, or transparent vapour. But still the matter has undergone no constitutional change. It is only necessary to remove the heat, and the particles will again come together and resume their primitive form. By cooling down the aerial gas into which the matters had been dissipated, or even by compressing them, so as to contract them into their original bulk and bring them together into their original proximity, the particles will once more resume their pristine form, the vapour will respectively appear as drops of liquid water, mercury, or lead, and those liquids being more condensed, will congeal into the original solid masses of solid ice, solid mercury, and solid lead. The most refractory gases have actually been found to obey this law, and we have no doubt that every substance in nature might

successively be presented to the senses in every one of these forms.

The following passages, taken from the *Timæus* of PLATO, present a remarkable accordance with these enlarged views of the constitution of steam and other gases:—"Let us therefore speculate concerning the nature and properties of fire and water, air and earth. This is the more arduous, because it is necessary to call into question, concerning each and all of them, whether they should be denominated liquid rather than ethereal, or aerial rather than solid; or why any thing should have one of these appellations rather than all. For, in the first place, that which we now call 'water,' being congealed, becomes (hard) as a stone or earth, but being melted and diffused becomes gas or air, and this inflamed becomes fire, and fire extinct becomes again congregated into air, and air collected and condensed forms mist and cloud, and these again, more compressed, form water, and from the water earth and stone are reproduced. And thus they, in an endless circuit, produce each other. Since, then, these now appear to be the same, who will assert that one of them is of the one kind rather than the other? It is most safe, therefore, to speak thus: that the thing we see is not absolute liquid, but something in the liquid state. That air is not necessarily a gas, but something in the gaseous state; not as being a particular thing of this or that specific nature, but that it is in such and such a condition."

"Let us then distribute the four modifications of matter into fire, earth, water, and air; and to earth let us assign an entical form, for it is the most immovable of all these kinds—to water that which is less movable than the other three—to fire the most easily movable form—and to air that which is intermediate."

It appears to us highly probable that the ancients knew more of the phenomena of steam than has been generally admitted. One evident cause of this mistake is the circumstance that no specific term equivalent to the word steam was generally used by them; and water, when heated, was said to be converted into an air. It is now almost perfectly established by the progress of modern science, that steam is an air, (or gas,) invisible and perfectly transparent, differing in none of its mechanical properties from common air or gas, and in no respect differing in its constitution from carbonic and other gases or airs which, at certain temperatures and pressures, do, like steam, leave the elastic aerial form and become condensed into steam. Many of the phenomena, therefore, for which the ancients use the word air, are effects of steam, or of steam mixed with air; and although they have not always carefully distinguished these separate effects, yet they have frequently made judicious use of them. While, therefore, it would be wrong to draw any parallel between the want of individualization manifested in their writings, and the high generalization of modern science, it would be equally wide of truth to deprive them, as has sometimes been attempted, of the merit of having discovered and used some of the properties of water in the aerial state, simply because they supposed it rarefied into an air, and confounded its phenomena with those of other gases, which, mixing with it, also contributed to the effect—as when we find that air rarefied by heat, and water rarefied into air, are mentioned.

HERO OF ALEXANDRIA, in his *Pneumatics*, has collected the science and inventions of the ancients, along with some of his own, into a systematic treatise, written in Greek, more than 120 years before the Christian era, some passages of which are identical with portions of modern treatises on pneumatics: and many portions of his apparatus may be found transformed into modern experimental models in cabinets of the physical schools. Now,

Steam-
Engine.

Steam-
Engine.

in the introductory portion of his work, we have such statements as these:—*Water is transformed into air by the action of fire. For the vapours of boiling caldrons are nothing else than attenuated moisture expanding into air.* Indeed, by the four elements the ancients appear to have meant the same things which we now designate by different terms. We comprehend all the material agents with which we are acquainted under the four great designations, solids, liquids, air, and ether. So exactly had the ancients their $\pi\upsilon\rho$ and $\alpha\eta\rho$, $\iota\delta\omega\rho$ and $\gamma\eta$, to which they assigned different regions according to their weight; first, the solids or earth, then the liquids above, next the aerial covering, and finally the region of ether extending indefinitely beyond. The moderns have shown that all bodies are probably capable of assuming any of the three states, and becoming solid, liquid, or fluid, according to the circumstances in which they are placed; and we have every reason to believe that Timæus, of whom Plato speaks with so much reverence, entertained the same idea, and believed that even the air might assume the state of a crystalline solid. It is not a little curious to find a mathematician of the present day giving it as a result of his calculus, that the air at a great distance from the earth is actually frozen into a crystalline solid by the extreme depression of temperature. He was probably not aware that his notion had been anticipated more than 2000 years. In this same work of Hero, we have descriptions and explanations of apparatus, in which the power of fire acting on moisture and air is made to produce phenomena of motion. He does not arrogate to himself the merit of these inventions, but has given them as principally a collection from the works of those ancients who had long preceded him—the ancient philosophers and mechanics.

His *Pneumatics* commence with a lucid and excellent dissertation on the properties of air as a medium for the communication of pressure and motion, and especially upon the nature and effects of a vacuum, subjects to be thoroughly understood by all who would master the theory of the steam-engine. It is, indeed, as the means of producing a vacuum, that steam obtains much of its value as a mechanical power. The mode of raising water by a vacuum is thus described by him:—"When they wish

Fig. 1.

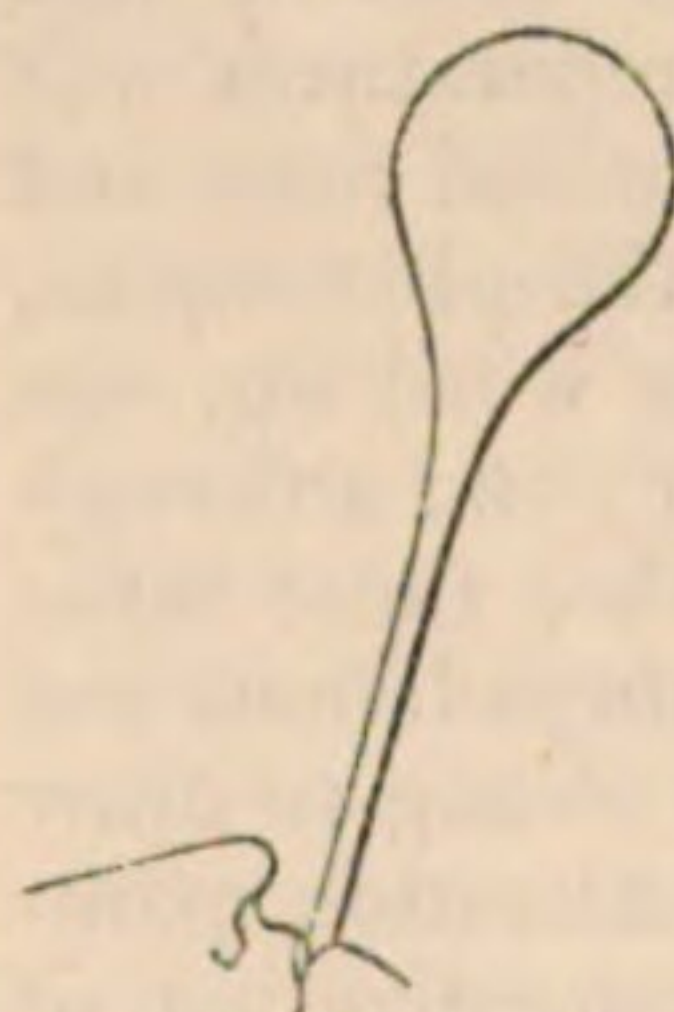


Fig. 2.

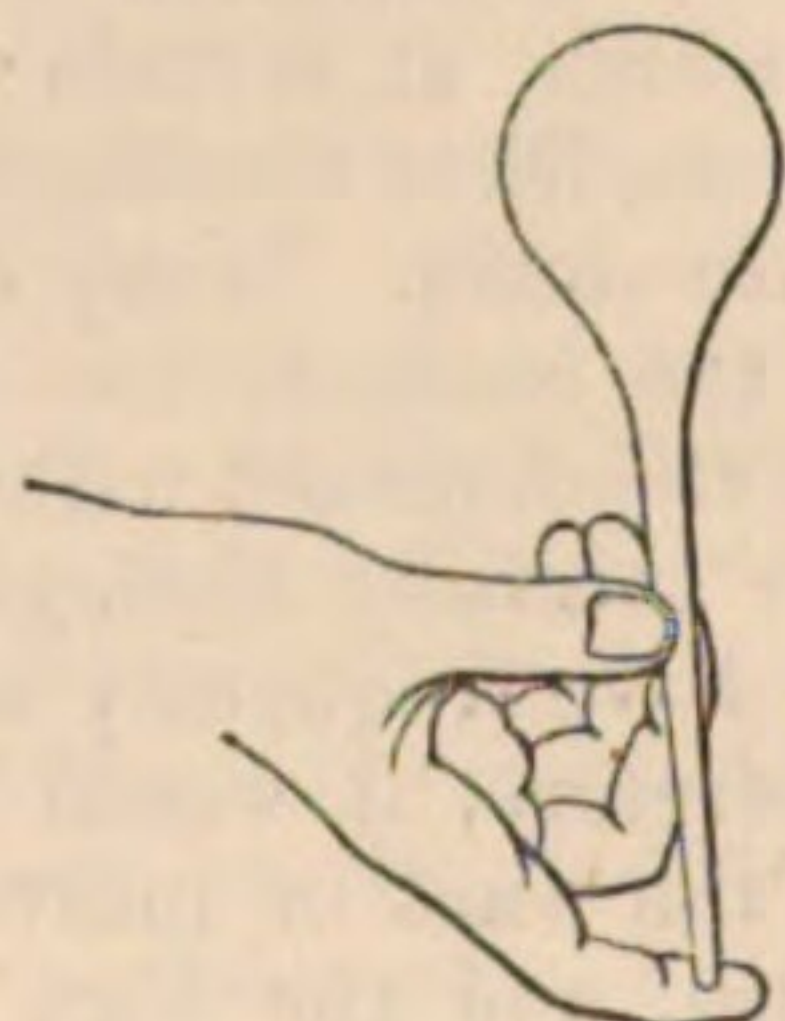
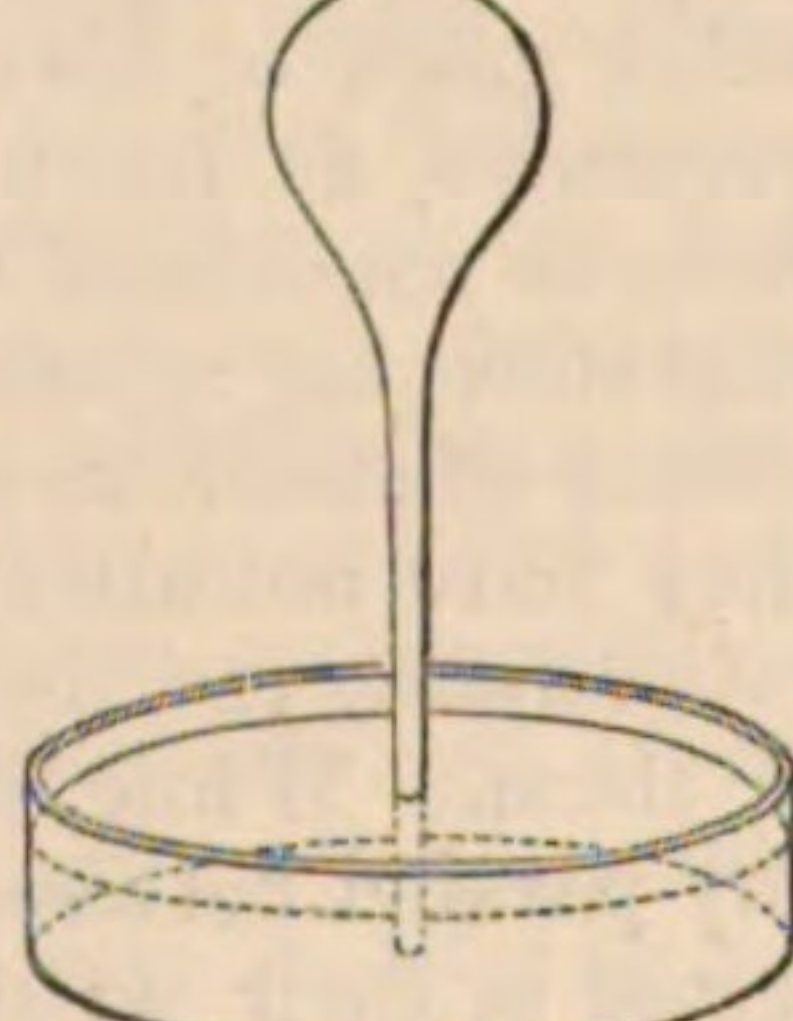


Fig. 3.



to fill with water the round medical glasses which have slender long necks, they suck out the air which is contained in them, and, closing the orifice with the finger, they invert them in the water, and on removing the finger the water is drawn up into the vacuous space, in contradiction to the usual law of fluids." He then proceeds to state that, "in like manner, air may be rarefied by heat even as other substances are; for water is changed by fire into air, the vapours from boiling caldrons being nothing else than expanded water taking the form of air, and that mists and clouds are nothing else than water raised in the air by heat, which are partly afterwards converted into air, while portions again descend in rain." He also attributes the origin of winds to the "expansion and contraction of air and moisture by the alternate heating and cooling produced by the sun's rays;" and illus-

trates the conversion of liquids into air or gas by the common observation, that, after a lamp has gone out, the vapour continues to rise up by the heat still left in it by the flame. Thus also, says he, a phial being filled with heated air and inserted in water, this air contracting will draw up water into the phial. Hence, he argues, that all airs consist of inconceivably small particles of matter, between which there are left wide vacuous spaces, so that, while the matter itself is incompressible, the volume occupied by the aggregate may be increased and diminished, and the air rarefied and condensed either by external force or the action of heat.

The following description of the manner in which the force of steam, issuing from a boiler, may be applied to supporting a weight, is given in the *Pneumatics*. "A boiler, perforated on the top, is placed on the fire. From the perforation there proceeds a tube, on whose extremity is fixed a hollow hemisphere perforated in like manner. If then we place a light ball in the hemispherical cup, it will follow that the vapour rising up from the boiler through the tube will support the sphere, and it will appear to dance."

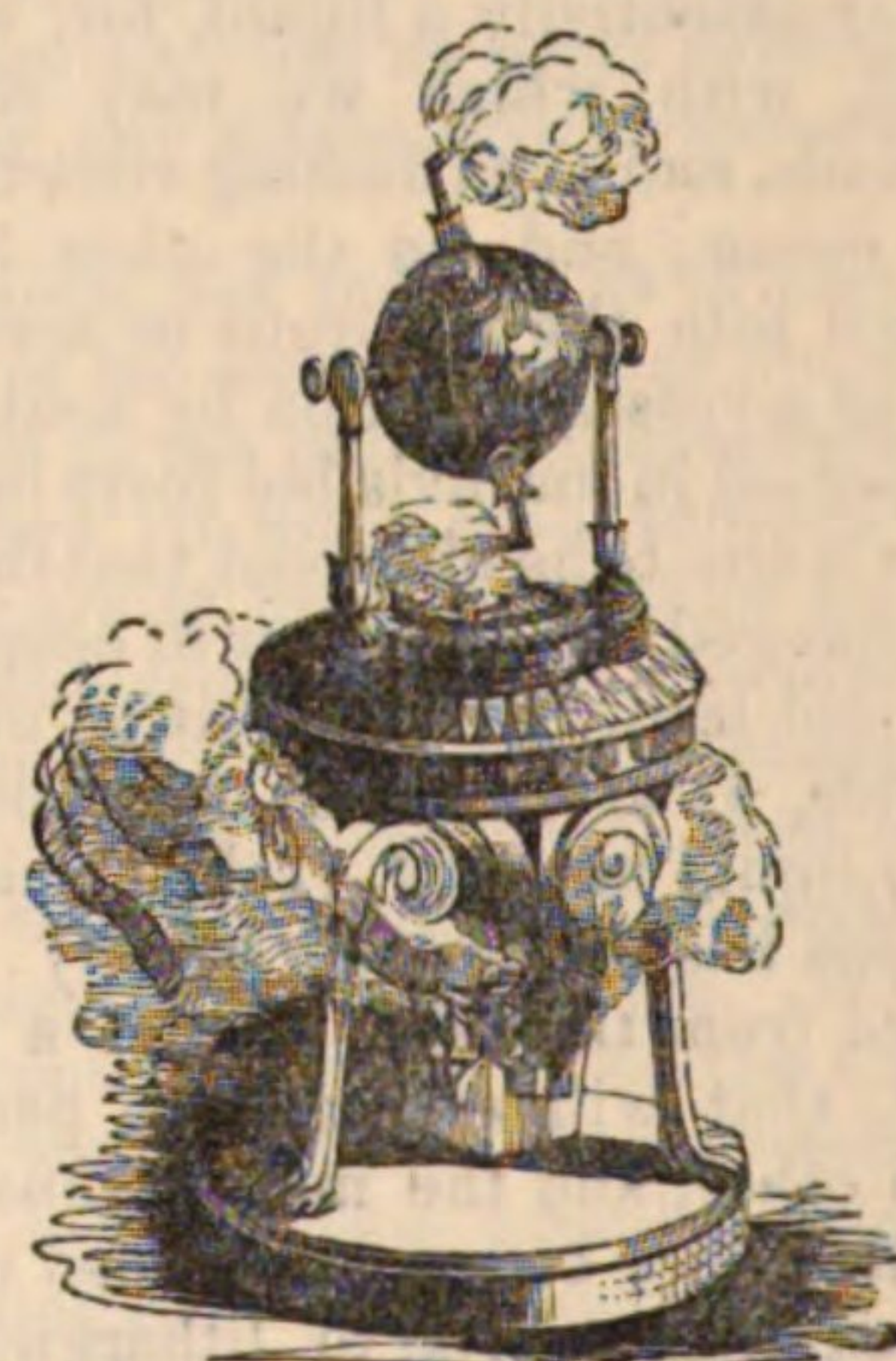
There is another apparatus in the *Pneumatics* for the purpose of producing a revolving motion by the action of steam—"by a caldron placed on a fire to give motion to a sphere around its axis. Let a boiler be set on the fire, and nearly filled with water, and let its mouth be closed in by a cover, and let it be pierced with an opening through the bent tube, whose extremity exactly fits into the hollow sphere. But at the opposite extremity of the diameter let there be an iron axis supported from the top of the cover; and let the sphere have two bent pipes at the ends of a diameter perforated along with it, and bent round in opposite directions; and let the bendings make right angles and be in the plane perpendicular to the axis. Then it will follow that, on the boiler being heated, the vapour rushing through the tubes into the sphere will rush out through the reversed pipes of the ball, and whirl it round on its axis."

The same apparatus, on similar principles, is next applied by Hero to the construction of a machine still more curious. The agent mentioned in this case is rarefied air, although the action is of precisely the same nature. Here the science of the philosopher appears to have been degraded to the base use of assisting an idolatrous priesthood in deceiving the populace by the resemblance of miraculous interference. "A fire having been kindled upon an altar, living figures will appear to

Fig. 4.



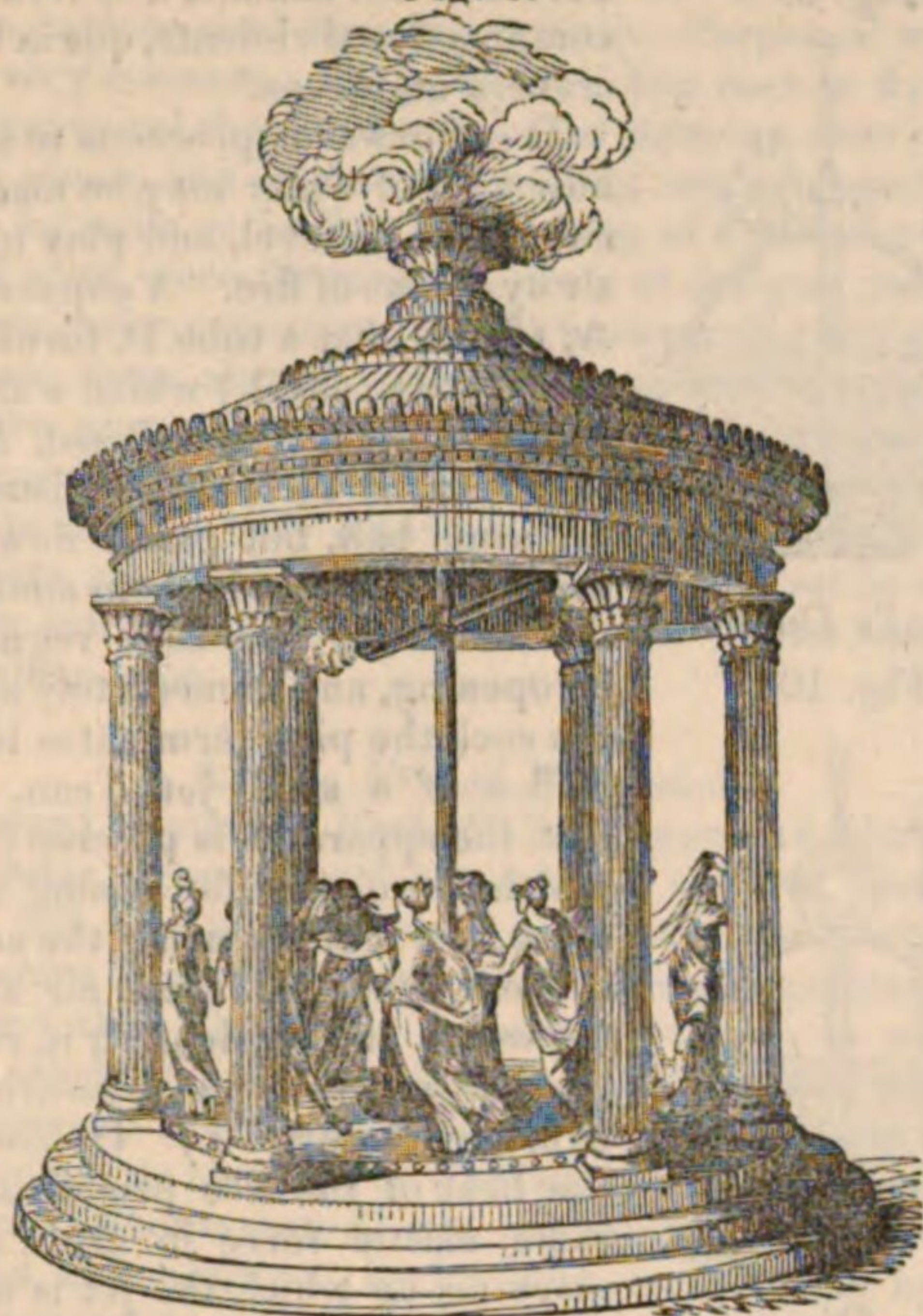
Fig. 5.



Steam-
Engine.

Steam-Engine. lead a choral dance, even although the altar itself be of transparent glass or horn. Through the epipyros a pipe is to be let down to the base of the altar, where it is to

Fig. 6.



revolve on an iron pin, the other end being passed through a tubular fitting attached to the epipyros. And this pipe is to have other little bent pipes attached to it, and perforated so as to communicate with it, which are to radiate opposite to one another around it, and turned alternately in opposite directions. There shall likewise be a drum attached to it, upon which the figures of the dance are to be set. Then, by the action of the kindled fire, the air, being warmed, will proceed into the pipe, and, from it being driven out through the bent tubes into the base of the altar, will turn round the pipe and its drum."

The following is probably the most excellent of all Hero's apparatus, inasmuch as in it the action of steam produced by fire from water is employed for the purpose of elevating a fluid above its level, and transferring it from one place to another. The design of the apparatus is still, unhappily, to serve the purposes of superstitious worship. "The fire of an altar having been lighted, two figures of living things are to assist at the sacrifices, and the figure of a dragon is to sybillate," (or give forth sounds to be interpreted as oracles.)

"There is to be a hollow basis or pedestal $\alpha\beta$, (fig. 7.) upon which is set the altar γ , having a tube δ descending to the middle of the basis, and is there separated into three branches; the tube $\epsilon\zeta$ passing to the mouth of the dragon, the tube $\epsilon\theta\kappa$ being carried to the vessel $\kappa\lambda$ containing wine, and placed at the top of the figure μ , and accurately joined into its cover; and into the third tube $\epsilon\nu\zeta$, which, in like manner, ascends into ζ , another vase holding wine, and is also accurately united to the top of the vase. Both ends of the two vases are to be carefully closed. There are to be in both the wine vessels

Fig. 7.

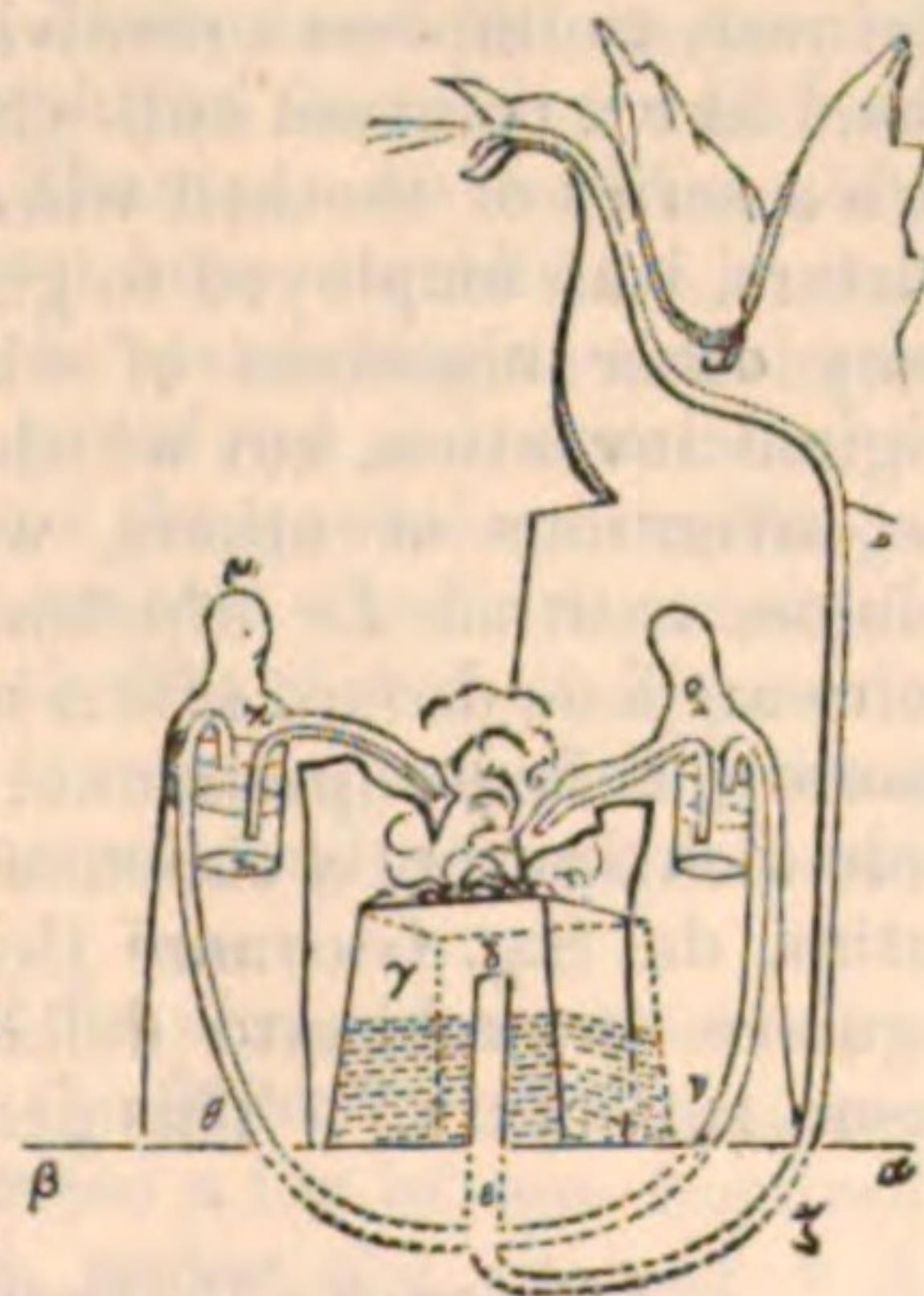
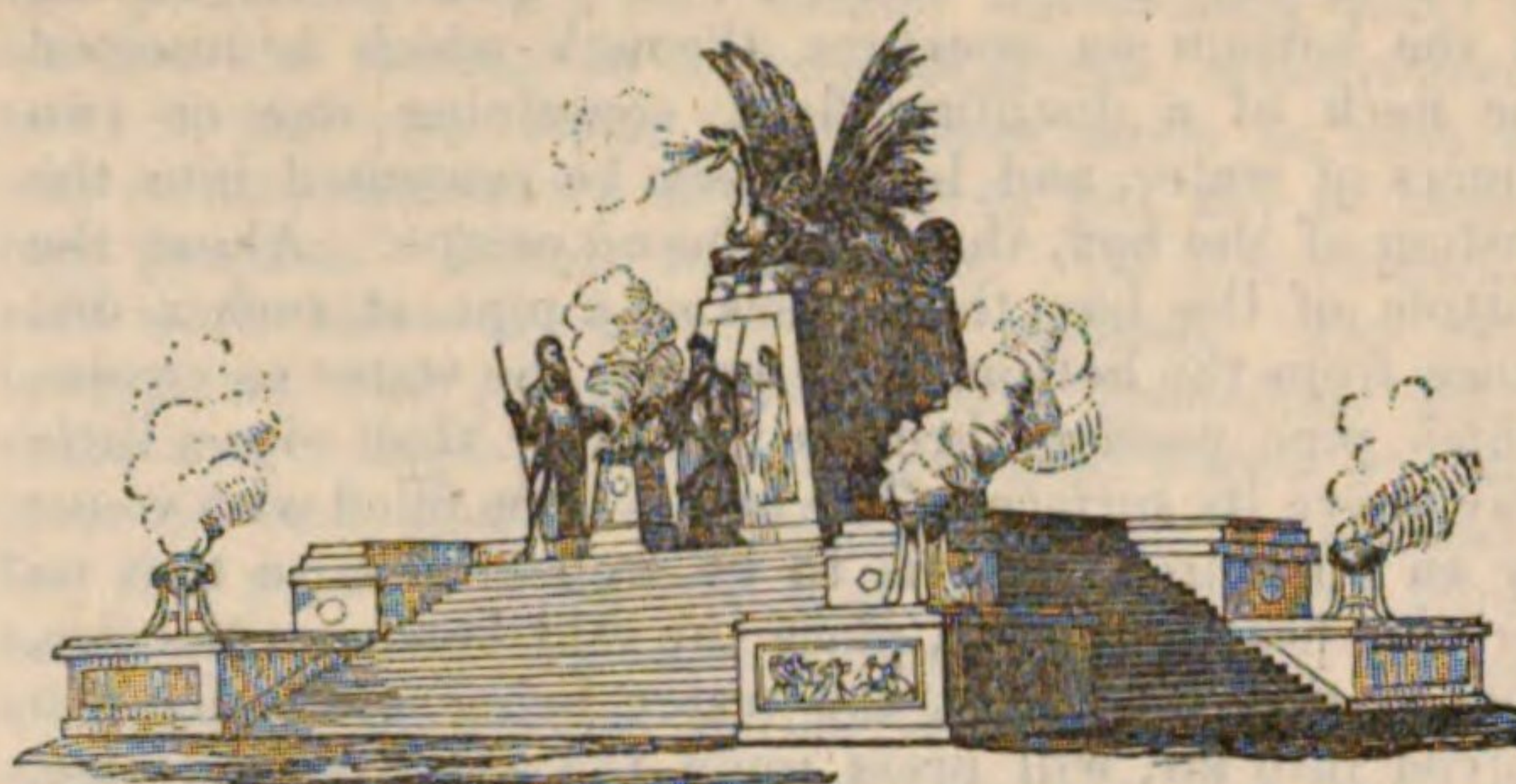


Fig. 8.



bent syphons $\epsilon\sigma\tau\kappa$, of which the one extremity is in the wine, and the other extremities, proceeding by an opening rendered perfectly close through the covers of the vases, are conducted to the hands of the figures officiating at the sacrifice. When, therefore, you are about to sacrifice, you must pour into the tubes a few drops lest they should be injured by heat, and attend to every joint lest it leak; and so the heat of the fire, mingling with the water, will pass in an aerial state through these tubes to the vases, and, pressing on the wine, make it pass through the bent syphons, until, as it flows from the hands of the living creatures, they will appear to sacrifice as the altar continues to burn, and the other tube being carried to the mouth of the dragon, will make it give forth sybilline sounds."

There appears to be considerable reason to suppose that, to their knowledge of the mechanical powers and the elements of machinery, the Egyptians added some acquaintance with the power of steam, applied, however, only to the degraded service of superstition. The statue of Memnon is said to have emitted sounds which Pausanias compares to those produced by the snapping of the strings of a harp. Strabo expressly states that he heard them; and Philostratus states, that when the sun shone strongly on the statue, sounds proceeded from its mouth similar to those of a stringed instrument. Hero of Alexandria in his *Pneumatics*, Salomon de Caus in his *Raisons des Forces Mouvantes*, Athanasius Kircher in his *Œdipus Egyptiacus*, and Cribellus in his *Machinosa Miracula Memnonis*, have all explained in different ways the mechanical arrangements by means of which effects of this kind might have been produced from the steam raised by the heat of the sun in close vessels contained in the statue, and having communication with organ pipes of different kinds.

The Romans appear to have done little for the mechanical arts, and nothing for the improvement of steam apparatus. It was not until the dawn of knowledge succeeded the darkness of the middle ages, that the light reflected from the works of Hero, and the older mechanicians, rekindled the flame of mechanical invention. The works of Archimedes and of Hero were read with great avidity, and formed some of the most popular productions of the young art of printing. The flame seems first to have been lighted in Italy, for we have editions and translations of Hero's *Pneumatics* rapidly succeeding each other; the Bologna edition of 1547, translated by Giov. Baptista Aleotti, was reprinted at Ferrara in 1589; Commandine's translation was published in 1575, Alessandro Giorgi's in 1592. There were other editions of less note; and thus in a single century eight or nine editions were issued. It was not to be expected that the seeds of mechanical knowledge, so widely sown, should not fall on some rich spots of soil, where they should bring forth fruit with increase.

Giambattista della Porta was one of the ablest and

Steam-Engine.

Steam-Engine.

most ingenious expositors of the principles of pneumatics. A work which he published on this subject contains the following passage:—"Make a box of glass or tin, having at the bottom an aperture, through which is inserted the neck of a distilling flask, containing one or two ounces of water, and let its neck be cemented into the bottom of the box, that there be no escape. About the bottom of the box there rises up a pipe at such a distance from the bottom as to permit the water to escape, which pipe passing through the cover shall rise a little way above its surface. The box is to be filled with water by an aperture which is to be well closed, so that no air may pass. Finally, place the said bottle on the fire, and heating it slowly, the water being gradually dissolved into air, will press upon the water in the case, and pressing with great force upon the water which issues through the pipe, (the steam) will not make its escape. And if we continue the application of heat, the whole of the water (in the flask) will be at last exhausted; and while the water is evaporating, the air (vapour or gas) will constantly press on the water in the vessel, and the water will continually issue out. The exhalation being finished, if you will measure how much water is out of the box; that which is in the place of the water gone out, will give the measure of the remaining water. Thus you find, from the quantity of water used, how much water was dissolved into so much air. And, in like manner, also, you can measure into how much of more rarefied air, air of the ordinary density can be dissolved."¹

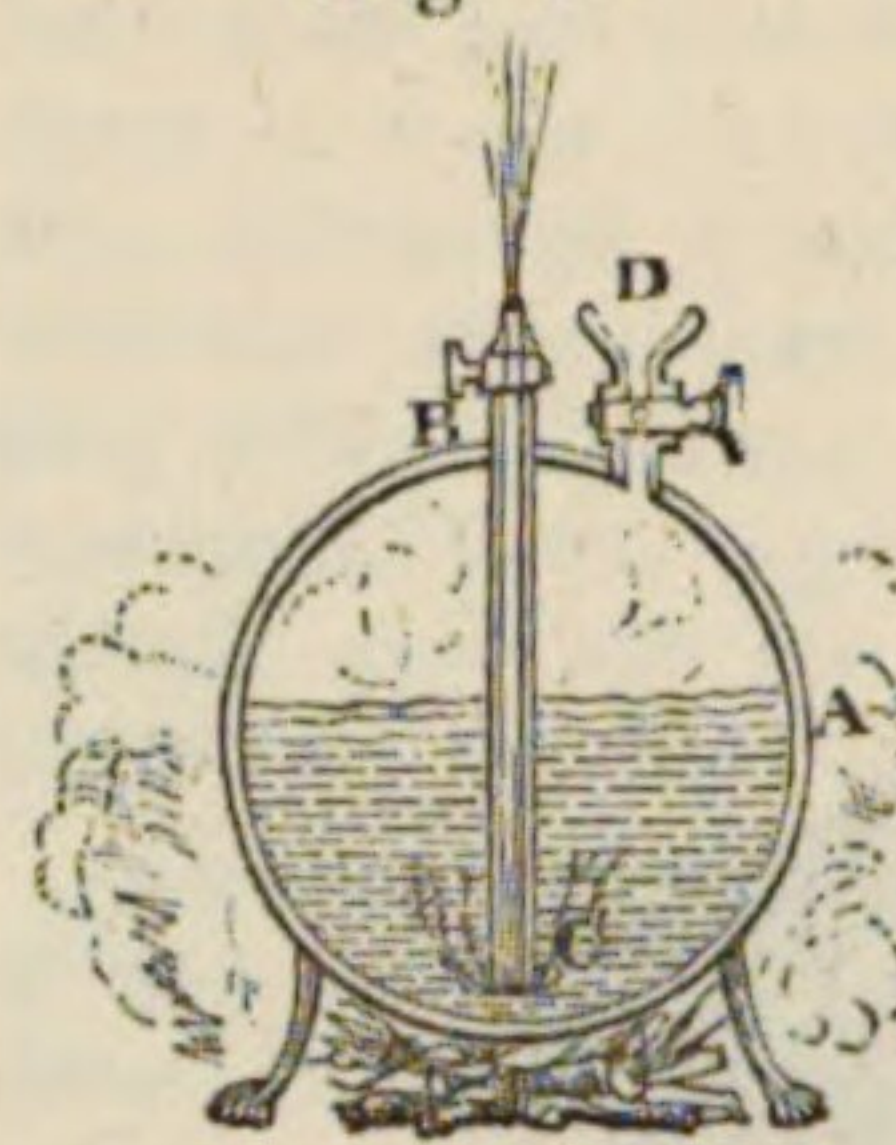
Here we perceive that the knowledge of the conversion of water into air or gas, taught by Hero's *Pneumatics*, was extending itself in that country, and leading to further contrivances; and we have also a beautiful and simple experiment, designed for the purpose of determining the philosophical question, which formed an interesting subject of research at a very recent period of physical enquiry, "how much aqueous gas is formed by a given quantity of water." The method is not perfect, for a considerable part of the vapour would be reconverted into water in the progress of the experiment; yet it shows an acquaintance with the fact, that water heated by fire is converted into aqueous air with sufficient force to raise water above its level, and form a running stream, although, in this case, of no very considerable height.

The spirit of invention, aroused by the first translation of Hero's works, did not confine itself to the country in which these works were first disseminated, but spreading gradually northwards, displayed itself in the works of an architect and engineer, Salomon de Caus, who had come to England in 1612, and was employed by the Prince of Wales, afterwards Charles I., to design grottoes, fountains, and other hydraulic ornaments, for the embellishment of the prince's palace at Richmond, and for the gratification of his Royal Highness's "gentile curiosité." These, with other machines, were published by him in a work entitled "*Les Raisons des Forces Mouvantes, avec diverses machines tant utiles que plaisantes; auxquelles sont adjointes plusieurs desseins de grottes et fontaines, augmentées de plusieurs figures.*" Frankfort, 1615, fol.

The work of De Caus is prefaced by an exposition of the principles of hydrostatics and pneumatics, evidently derived from the writings of Archimedes and of Hero. Among other things, he states that the violence with which water is dissolved into air by means of fire is very great, and that it is quite certain that a ball of copper containing water, if placed on a fire, would be infallibly

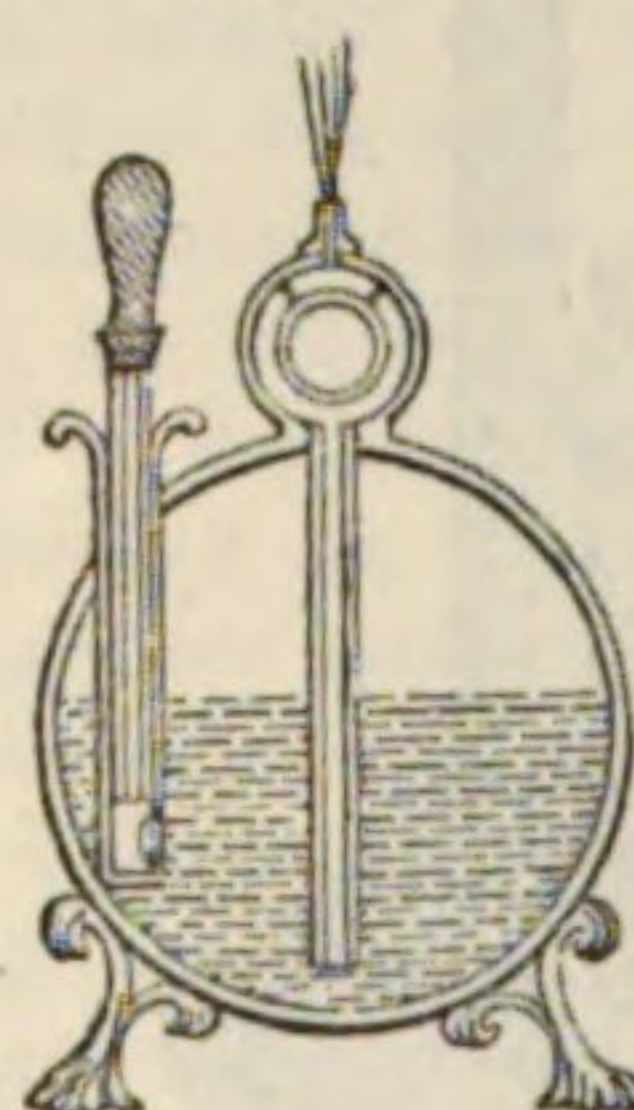
burst. "La violence est grande quand l'eau s'exhale en air par le moyen du feu il est certain que si l'on met la dite balle sur un grand feu, en sorte qu'elle devienne fort chaude, il se fera une compression si violente, que la balle crevera en pièces."

Fig. 9.



De Caus's Diagram.

Fig. 10.



Hero's Diagram.

There seems no reason to doubt that Salomon de Caus was a Frenchman by birth, and he is said to have been a native of Normandy.² In dedicating to the French monarch an edition of his work, he describes himself as one of his Majesty's subjects. After leaving England, he settled in Germany, where the Elector Palatine intrusted him with the superintendence of his buildings and of his gardens. He finally returned to France, and died there about the year 1630. He has sometimes been confounded with Isaac de Caus, a native of Dieppe, and a descendant of the same family. The latter published a work, entitled, "*Nouvelle Invention de lever l'Eau plus haut que sa source, avec quelques machines mouvantes par le moyen de l'eau, et un discours de la conduit d'icele.*" Lond. 1644, fol. This work contains many machines identical with those described by Salomon de Caus; and the similarity of subject, treatment, and title of the two, has led those into much confusion who may not have examined both. Even the pains-taking and industrious Stuart seems to have been deceived, and calls Isaac's book a later edition of Salomon's.

The direct emission of steam from an orifice of the boiler, which had been used by Hero to sustain the ball in the air, was applied by Branca, an Italian architect and engineer, to impress a revolving motion on the vanes of a wheel like a common mill-wheel, and this communicating with a series of toothed wheels to a series of pestles in mortars, was employed to give them motion. This, and many other machines of which he does not claim the original invention, but which he states he collected from the inventions of others, were published in a quarto volume, entitled *Le Machine*. "Volume nuovo et di molto artificio da fare effetti maravigliosi si tanto spiritali quanto di animale operatione: arricchito di bellissime figure conle dichiarazioni a ciascuna di esse in lingua volgare et Latina, del Sig. Giovanni Branca, cittadino Romano, ingegniero et architetto della sta. casa di Loretto. In Roma, M.DC.XXIX." This period appears to have teemed

Steam-Engine.

¹ J. B. Portæ *Pneumaticorum libri tres*. Neapoli, 1601, 4to.

² *Biographie Universelle*, tom. vii. p. 433.

Steam-Engine.

Marquis of Worcester's Inventions.

with curiosities of mechanical invention; and the learned virtuoso who would take the trouble of ransacking the mechanical productions of the sixteenth and seventeenth centuries, would be able to collect materials for an interesting, curious, and amusing volume. Perpetual motions were very common; wings for enabling men to fly in the air, mechanical chariots for a similar purpose, conveyances to the moon, and engines for making continual and cheap music by mills or by fire, for rocking of cradles and turning of spits, were favourite subjects of design; and many of these curious contrivances, without serving any definite purpose, form elegant and curious pieces of apparatus. We are now passing from the era of the curiosities of mechanical contrivance, into that period in which the same principles that actuated the toys of Hero and the automata of Kircher were to be applied to set in motion mighty machines for the advancement of the welfare of the human race.

2. The Era of Worcester.

Edward Somerset, Earl of Glamorgan and Marquis of Worcester, invented and constructed the first steam-engine. His title to this honour has been the subject of dispute, some historians attributing to him a greater share of merit than there was sufficient evidence to warrant, while others deprive him of even that honour to which he possesses an indefeasible claim. His life is one of the most romantic chapters of English history. Enterprising, generous, disinterested, and confiding, he was at once beloved and betrayed by his king, loaded with honours and reduced to poverty; at one time exercising almost without control the functions of the sovereign, conferring dignities from the rank of marquis down to baronet, and at another thrown into prison, and begging from a creditor the paltry loan of five pounds. Possessing inventive genius of the highest order, he was considered a mad enthusiast because his speculations were advanced so far before the age in which he lived, and has been set down a quack and impostor by men incapable of comprehending the nature or appreciating the value of his creations. The slow march of knowledge and of time has at last revealed the worth, and established the character, of an illustrious and unfortunate man of genius, who only lived to complete his mighty design and carry it happily into effect, and having done his work, went to take his rest in death.

That the Marquis of Worcester was acquainted with the nature and force of steam, no one has ever disputed; but it has been matter of serious doubt whether the machine which he has described had ever any real existence. Hitherto we have had nothing more than circumstantial presumptive evidence of the actual construction of the marquis's steam-engine. It is only a few years since the industry of the indefatigable antiquary Robert Stuart has presented us with an historical document of undoubted authenticity, affording undeniable proof of the existence and efficiency of one of the engines of the Marquis of Worcester, of more than two horse power, employed for raising water on the Vauxhall side of the river Thames. As the Marquis's title to the invention has not yet been established in any of the numerous treatises on the steam-engine that have hitherto appeared, and as the proof we are now able to adduce must for ever set at rest the querulous cavillings of those otherwise respectable writers who have attempted to controvert the great truth that the steam-engine is a machine wholly of British invention, we shall give a short account of what the marquis undoubtedly accomplished.

We are principally indebted for our acquaintance with the mechanical inventions of the Marquis of Worcester to a work in which he published a list of one hundred of his mechanical inventions, under the title of "A

Century of the Names and Scantlings of such Inventions as at present I can call to mind to have tried and perfected, which (my former notes being lost) I have, at the instance of a powerful friend, endeavoured now, in the year 1655, to set these down in such a way as may sufficiently instruct me to put any of them into practice." Lond. 1663, 12mo. Of this remarkable work there are several other editions. The following are the passages which have immediate reference to the high-pressure steam-engine which he had invented and made. It may be proper to premise, for the purpose of preventing the supposition from being entertained that it was impossible to get devices of so complex a nature carried into effect at a period when the mechanical arts of construction had made so little progress, that he had employed constantly in his service, during a period of five-and-thirty years, one of the most eminent artificers of the time, one Caspar Kalltoff, and that he had provided him with suitable workshops, tools, and machinery, at an expense of more than ten thousand pounds. It thus appears that the marquis was no mere schemer, but that he submitted his devices to the test of experiment; and it is merely not passing the bounds of credibility to suppose, that, with fertile resources, an active and inventive mind, the best tools, an "unparalleled" artificer, and the expenditure of great sums of money, he had in five-and-thirty years constructed machines of such perfection as no other artist of his age had accomplished, and few of the hangers-on of a royal court could understand or appreciate. No one who is acquainted with the modern high-pressure steam-engine can fail to recognise it in the following specification, which, be it observed, was given by the marquis rather for the purpose of exciting curiosity than gratifying it—for stating the capabilities of his engine than explaining its principle, which he wished to keep secret for the purpose of obtaining a patent.

"Invention 68.—An admirable *most forcible way to drive up water by fire*; not drawing or sucking it upwards, for that must be, as the philosopher calleth it, '*intra spheram activitatis*,' which is but at such a distance, *but this way hath no bounder, if the vessels be strong enough; for I have taken a piece of a whole cannon, whereof the end was burst, and filled it three quarters full, stopping and screwing up the broken end, as also the touch-hole, and making a constant fire under it; within twenty-four hours it burst and made a great crack: so that, having found a way to make my vessels so that they are strengthened by the force within them, and the one to fill after the other, I have seen the water run like a constant fountain forty feet high.* One vessel of water, rarefied by fire, driveth up forty of cold water; and a man that attends the work is but to turn two cocks, that one vessel of water being consumed, another begins to force and refill with cold water, and so successively."

The internal evidence of the truth of this description is too strong to be resisted. We cannot say what ideas it may have suggested to such a man as Lord Orford, who was probably as ignorant of mechanical principles as he was devoid of candour and charity to a man of principles and religion different from his own; but to any one conversant with the mechanical contrivances and treatises even of that time, it was scarcely possible to read the sentence without forming a distinct conception of a similar apparatus to that here described by the marquis. We shall see that the description was so perfect as to enable a subsequent mechanician to reconstruct the machine of the marquis, with some additions, and produce an effective machine for draining mines. We see, too, how philosophical was the process by which he

Steam-Engine.

Marquis of Worcester's Inventions.

Steam-Engine.

Marquis of Worcester's Inventions.

advanced to the construction of his machine. He made experiments of a conclusive nature on the boundless force of steam. He found that the only impediment to its use was the want of sufficiently strong boilers; and his having found a way to make his vessels so as to be strengthened by the force within them, merely shows that he overcame the difficulty of making steam-tight joints by using internal flanges, which should become tightened by the pressure of steam within them. There is also internal evidence of the genuineness of his description in the statement of the quantity of water converted into steam for the effect of raising the water,—“one vessel rarefied by fire driveth up forty of cold water,” is a measure of the power of steam far within the compass of its capability. Even under most unfavourable circumstances, an unprincipled exaggerator would not have contented himself with this moderate statement of its actual power.

But we have not yet concluded the marquis's description of the nature of his stupendous prime-mover; for his mind, in dwelling upon its principles, applications, and powers, gradually became assured that his engine was to become the most important and powerful agent in the whole world, and appears, even at that remote era, to have obtained a glimpse of the multifarious avocations and powers of the modern steam-engine. He proceeds to describe “an engine so contrived, that working the *primum mobile* forward and backward, upward or downward, circularly or cornerwise, to and fro, straight upright or downright, yet the intended operation continueth and advanceth, none of the motions above mentioned hindering, much less stopping the other, but unanimously and with harmony agreeing, they all augment and contribute strength unto the intended work and operation; and therefore I call this a semi-omnipotent engine, and do intend that a model thereof be buried with me.”

“How to make one pound weight to raise an hundred as high as one pound falleth, and yet the hundred pound descending doth what nothing less than one hundred pounds can effect.”

“Upon so potent a help as these two last-mentioned inventions, a water-work is, by many years' experience and labour, so advantageously by me contrived, that a child's force bringeth up, an hundred foot high, an incredible quantity of water, even two foot diameter, so naturally, that the work will not be heard into the next room; and with so great ease and geometrical symmetry, though it work day and night from one end of the year to the other, it will not require forty shillings' reparation to the whole engine, nor hinder one day's work; and I may boldly call it the most stupendous work in the whole world; and not only with little charge to drain all sorts of mines, and furnish cities with water, though never so high seated, as well as to keep them sweet, running through several streets, and so performing the work of scavengers, as well as furnishing the inhabitants with sufficient water for their private occasions, but likewise supply rivers with sufficient to maintain and make them portable from towne to towne, and for the bettering of lands all the way it runs, with many more advantageous and yet greater effects of profits, admiration, and consequence; so that, deservedly, I deem this invention to crown my labours, to reward my expenses, and make my thoughts acquiesce in the way of further inventions.”

To any one who is familiar with the advantages which such cities as London derive at this moment from having the water raised up by fire and distributed through the highest houses for private use; who has witnessed the incredible quantity of water brought up by a Cornwall, or Newcastle, or Staffordshire steam-engine from enormous depths, by the descent of a piston not one thousandth

part of the weight which it raises through an equal height; who has observed the elastic force of steam as a *primum mobile* in a cylinder performing in any and every position its multifarious duties, and that a child's force is sufficient to control and guide the operation of that stupendous power, it must be most obvious that we have only carried to perfection that engine which the Marquis of Worcester first conceived and made.

Some points in the statement of the marquis, which had not formerly been noticed, have received considerable elucidation, by a manuscript account of his inventions, discovered a few years ago by Mr Robert Stuart, and by another document, of no small importance in this question, which was brought to light by the zeal and industry of the same writer, viz. a Diary of Cosmo de' Medici, Grand Duke of Tuscany, who visited England about the year 1656, in which he gives an account of the engine invented by the Marquis of Worcester, which he had an opportunity of witnessing in operation at Vauxhall.

The Condensing Steam-Engine of Captain Savary.

About thirty years after the marquis's death, which happened in 1667, the condensing steam-engine was invented by an Englishman, Captain Thomas Savary, and was by him introduced for draining mines, raising water for buildings and gardens, and generating a revolving mechanical power. He exhibited a model of it to the Royal Society of London in 1699. (*Phil. Trans.* vol. xxi. p. 228.) We have seen that the marquis's model appears to have been placed on or below the level of the water to be raised, and that his vessels being filled, their contents were raised by the elastic force only of the steam. Mr Savary, on the other hand, erected his engine at a height of nearly thirty feet above the level of the water. A large close vessel was filled with steam; this steam was reconverted, by cooling the outside of the vessel, into water, leaving the large space it had formerly occupied vacuum; into this vacuum water was raised, as into the vacuum of a common sucking-pump, by atmospheric pressure, and so within the limit of atmospheric pressure, raised twenty-eight or thirty feet. After this was accomplished, the water was further raised through any remaining height by the elastic force of the steam, just as in the engine of the Marquis of Worcester. But the improvement was great. The same force of steam, strength of vessels, and consumption of fuel which was sufficient on the marquis's plan to raise water thirty feet high, would be capable first of drawing up the water thirty feet, and then raising it thirty feet more; or doing double the work, or sixty feet of height on Savary's plan. This was certainly a notable improvement.

There has been considerable discussion among the historians of mechanics regarding the merits of Worcester and of Savary. Those who have thought proper to praise the inventive talent of the one, have thought it essential to their purpose to depreciate the merit of the other. We think their claims rest on independent grounds. The Marquis of Worcester expressly disclaims the use of a vacuum, which, on the other hand, is the distinguishing feature of Captain Savary's, when he says, “not by drawing or sucking it upward, for that must be as the philosopher calleth it, *infra sphaeram activitatis*, which is but at such a distance; but this way (by high-pressure) hath no bounder, if the vessels be strong enough.” It appears, therefore, to us, that the inventions were quite independent and different; and we have no hesitation in admitting it as exceedingly probable, that when Captain Savary added the principle of high-pressure to his own principle of a vacuum from condensation, he was not unacquainted with the marquis's works, and even with his engine for raising water by fire, for which he had obtained a pa-

Steam-Engine.

Steam-Engine.

Desaguliers's Evidence on Savary's Engine.

tent, and which he had erected at Vauxhall. While we have thus expressed our own opinion of the independence of their claims, we must not omit the opinions of others who lived nearer to the epoch of these rival candidates.

Dr Desaguliers, an eminent mechanist, and an experimental philosopher of considerable reputation, has given, in his *Course of Experimental Philosophy*, vol. ii., an account of the "fire-engine," and after adverting to the claims of the Marquis of Worcester, makes the following statement in regard to Savary:—"Captain Savary having read the Marquis of Worcester's book, was the first who put in practice the raising water by fire, which he proposed for the draining of mines. His engine is described in Harris's *Lexicon*, (see the word ENGINE,) which, being compared with the Marquis of Worcester's description, will easily appear to have been taken from him; though Captain Savary denied it, and the better to conceal the matter, bought up all the Marquis of Worcester's books that he could procure in Paternoster Row and elsewhere, and burn'd 'em in the presence of the gentleman, his friend, who told me this. He said that he found out the power of steam by chance, and invented the following story to persuade people to believe it, viz., that having drunk a flask of Florence at a tavern, and thrown the empty flask upon the fire, he called for a bason of water to wash his hands; and perceiving that the little wine left in the flask had filled up the flask with steam, he took the flask by the neck and plunged the mouth of it under the surface of the water in the bason, and the water of the bason was immediately driven up into the flask by the pressure of the air. Now, he never made such an experiment then, nor designedly afterwards, which I thus prove:

I made the experiment purposely with about half a glass of wine left in a flask, which I laid upon the fire till it boiled into steam; then putting on a thick glove to keep the neck of the flask from burning me, I plunged the mouth of the flask under the water that filled

Fig. 11.



Fig. 12.



Dr Desaguliers's Experiment.

a bason; but the pressure of the atmosphere was so strong, that it beat the flask out of my hand with violence, and threw it up to the ceiling. As this must also have happened to Captain Savary, if ever he had made the experiment, he would not have failed to have told such a remarkable incident, which would have embellish'd his story."

We have performed the doctor's experiment frequently, with various results. If the mouth of the flask happens to be large and its neck short, the water very cold, and the flask very perfectly filled with steam, the effect is exactly what Desaguliers describes; for the vacuum being suddenly and completely formed, the flask is first pressed down towards the basin, which the hand resists by sustaining the flask in the opposite direction, and just then the water rushes with great velocity up into the vacuum, and striking on the bottom of the flask, now turned upwards, is apt to knock it suddenly out of the hand, especially when held merely by a soft glove. But if, on the other hand, the flask has a narrow mouth and long neck, and if, when inverted, its neck be allowed to rest on the bottom of the vessel, and if the water in the basin be

VOL. XX.

not very cold, it will rise slowly and gently, and the flask will be completely filled.

The doctor's inference is not, therefore, perfectly just to Savary, and allowing that Savary had read Worcester's book, he would not find in it any principle of this nature, but an express exception from it, as we have already stated.

Stephen Switzer, author of a *System of Hydrostatics and Hydraulics*, published at London in 1729, takes a different view of the matter. In the chapter "On the Engine for raising Water by Fire," he gives the following account of it:—"Amongst the several engines which have been contrived for the raising of water for the supply of houses and gardens, none has been more justly surprising than that for the raising of water by fire; the particular contrivance and sole invention of a gentleman with whom I had the honour, long since, to be well acquainted—I mean the ingenious Captain Savary, some time since deceased, but then a most noted engineer, and one of the Commissioners of the sick and wounded.

"This gentleman's thoughts (as appears by a preface of his to a little book entitled *The Miner's Friend*) were always employed in hydrostatics or hydraulics, or in the improvement of water-works; and the first hint from which it is said he took this engine, was from a tobacco-pipe, which he immersed to wash or cool it, as is sometimes done. He discovered that the water was made to spring through the tube of the pipe in a wonderful and surprising manner; though others say that the learned Marquis of Worcester, in his *Century of Inventions*, (which book I have not seen,) gave the first hint for this raising water by fire.

"It was a considerable time before this curious person, who has been so great an honour to his country, could bring this, his design, to perfection, on account of the awkwardness of the workmen who were necessarily to be employed in the affair; but at last he conquered all difficulties, and procured a recommendation of it from the Royal Society, (*Phil. Trans.*, 252,) and soon after a patent from the Crown, for the sole making this engine; and I have heard him say myself, that the very first time he play'd, it was in a potter's house at Lambeth, where, though it was a small engine, yet it (the water) forced its way through the roof, and struck up the tiles in a manner that surprised all the spectators."

"About the year 1699, he wrote a small pamphlet or treatise concerning this engine which I have just now mentioned, wherein he has exhibited a draught of it; but as that consisted of a double receiver, and a great many particulars not so easy for a learner at first sight to understand, I have, first of all, inserted that draught of it, and the account thereof, which Mr Bradley, in his new improvements of planting and gardening, has given us of that at Cambden House, it being an engine of Mr Savary's own invention, and which is the plainest and best proportioned of any that I have seen.

"A the fire; B the boiler, a copper vessel of a spherical figure in which the water is boiled and evaporated into steam, which passes through the regulator C, which opens to let it into D the steam-pipe, of copper, through which it descends into E the receiver, which is a vessel of copper also, that at first setting to work is full of air, which the steam discharges through F the engine tree, and up the clack valve at K, and so the air ascends in L the force pipe.

"After E is void of air, which is found by its being hot (with steam) all over, then stop the steam at C, and throw a little cold water on the outside of the hot receiver E, so as to cool down the steam in the inside, and so make it resume the condition of water, leaving E a vacuum, into which the pressure of the atmosphere will raise a column

Steam-Engine.

Switzer's Evidence on Savary's Engine.

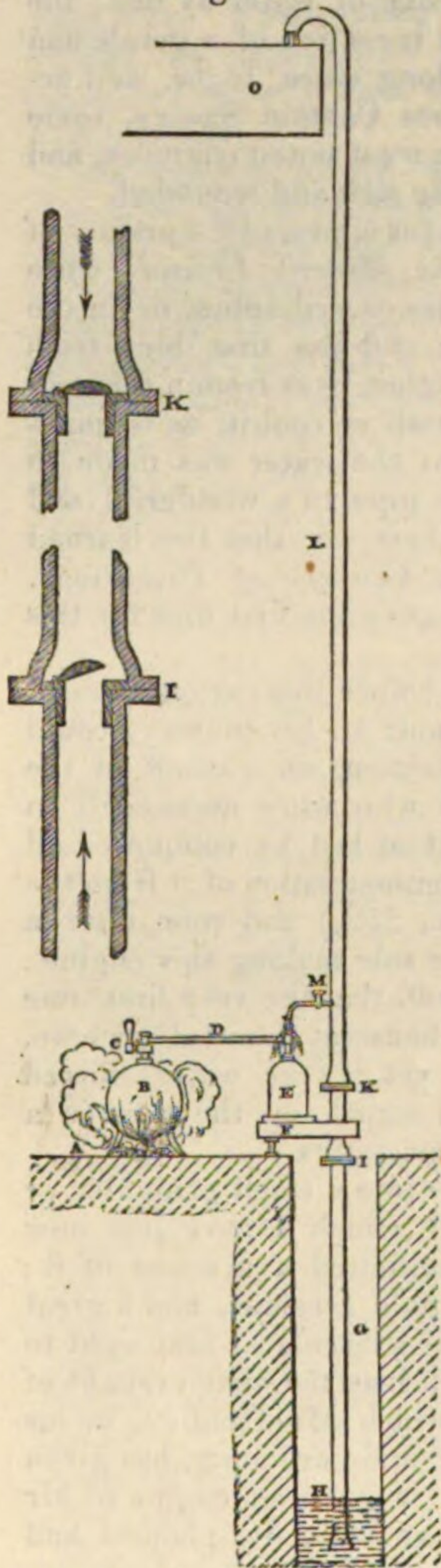
Switzer's Description of Savary's Engine.

Steam-Engine.

of water through the sucking pipe G from H, the pond, well, or river.

"This being done, and the receiver now being filled with water, first turn C, and let the steam pass into the receiver E, and it will force the water therein through F by K up to L, which water cannot descend because of the clack valve I. When E is thus emptied, which may be easily perceived by its being hot, as before, turn C, and confine your steam in B, then open the cock M, which will let a little cold water into E, and that, by condensing the steam in E, will cause the water to ascend immediately from H and replenish E. Then turn C to let the steam into E, and it will force the water out of it up L, into a cistern at O, placed at the top to receive it. Then confine your steam at C as before, and turn M for the space of a second or two of time, and E will be refilled, and may again be discharged up L as before; so that this work may be continued as long as you please. The valves placed in the pipes at I and K are shown on a larger scale at the side, and will enable the reader to see how they permit the water to ascend, but prevent its return by the weight of the water pressing down the clack.

Fig. 13.



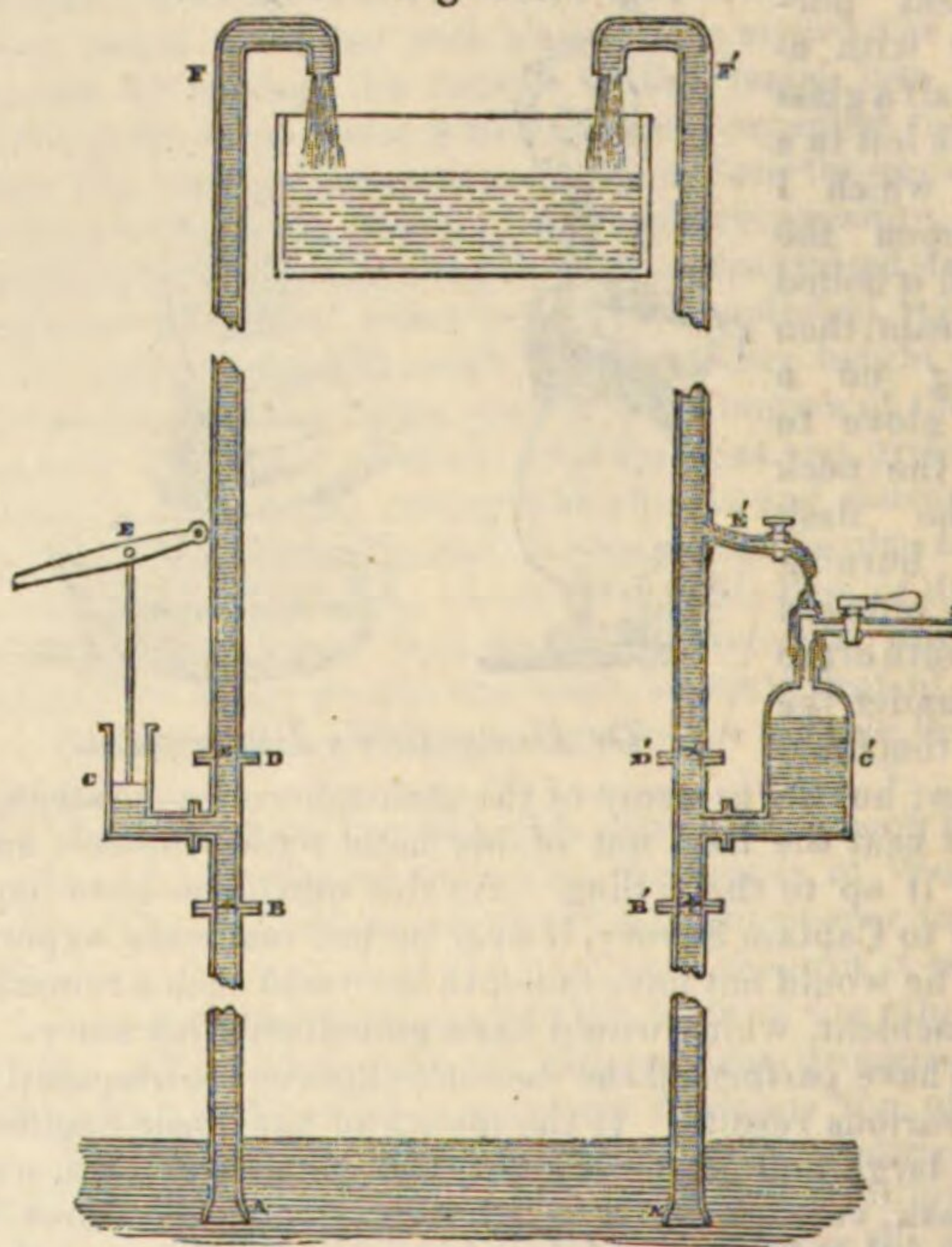
"It must be noted that this engine is but a small one in comparison of many others of this kind that are made for coal-works; but this is sufficient for any reasonable family, and other uses required for it in watering all middling gardens. Its dimensions are as follows:—the pipe from the surface of the water to F is 16 feet, and from F to the upper cistern 42 feet high; the diameter of both pipes 3 inches, and of the steam-pipe D, an inch. The receiver E holds 13 gallons of water, and the boiler three times that quantity.

"This engine will throw up four of the receivers full in one minute=52 gallons, which is 3110 gallons an hour, =52 hogsheads an hour, or 1248 hogsheads in 24 hours. The prime cost of such an engine is about L.50, as I myself have had it from the ingenious author's own mouth, and the quantity of coals required to work it about one bushel in twenty-four hours. The expense is not considerable to what horse-work is, which must be shifted twice or thrice a-day, especially in all wood or coal countries."

It seems to us very probable, from the form of Savary's engine, that it was taken directly from that of a common drawing and forcing pump, with the substitution of the force of steam only for that of the pump piston. In Fig. 14, A B C D E F represent a common forcing pump, as given in the hydraulic works of that epoch. A' B' C' D' E' F' are the parts of one of Savary's steam-pumps. In the case of the common pump, the solid piston or plug at C, exactly fitted to the cylindrical chamber at C, is forced

down by the lever E upon the water in the chamber C, which is pressed out through the pipe at the bottom, and being prevented from passing down to A by the closing valve B, is carried up through the open valve D, and raised towards the top of the reservoir F. When the chamber C is thus emptied, the piston is again raised, and as it is perfectly tight, so that no air can enter, the water is carried up through the valve B, which only opens upwards, and thus the vacuum at C is filled from below, by atmospheric pressure, with water, which is again to be forced back by the descent of the piston; but as the valve B closes by the pressure above it, and the valve D opens upwards, the water is carried upwards and delivered at F, the top of the reservoir. For the solid piston of the pump we have only to substitute the agency of steam, and we have Savary's machine. The close chamber C' being conceived full of water, steam from the boiler is admitted by S', and, by its elastic force, presses downwards on the surface of the water at C', so as to force it out of the receiver; and finding no exit by the closed valve B', it is forced through the rising valve D' towards the receiver F'; in these circumstances, the little jet brought from the pipe E' is allowed to throw cold water for a second or two on the close chamber C, now filled with steam, which is immediately condensed into the small quantity of water from which it was originally formed, and leaves the remaining space vacuous—into which vacuum, as in the former case, water is carried up by the force of the atmosphere, so as again to replenish the chamber C', as at first, with water, which is in its turn to be acted on by the elastic force of steam admitted through S', and carried up through D' F' to be delivered at F'.

Fig. 14.



The reader who has followed this examination of Savary's steam-engine in its earlier form, is now prepared to understand the more complex but more efficient form in which the engine was more generally used. This form is that of the double receiver. The form hitherto examined does not produce a uniform stream, because the receiver, after having emptied its contents, requires a considerable interval to fill again. The double machine renders the stream nearly constant, for there are two receivers placed in communication with the boiler and the

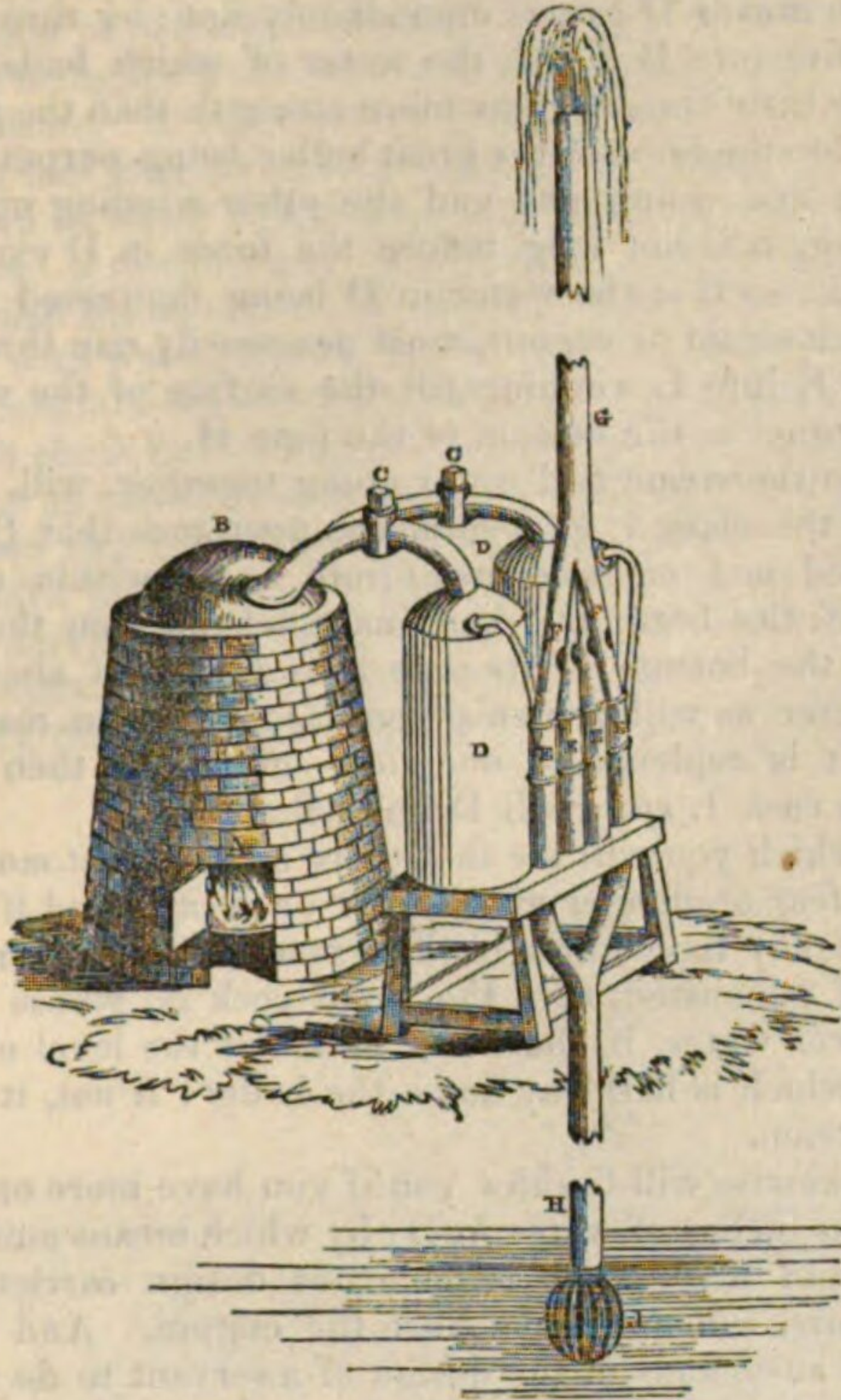
Savary's
Engine a
Steam-
Pump.

Steam-Engine.

water-pipes, in such a manner that when the one is being filled the other is being emptied, and when the latter is again being charged with water from below, the other is discharging its contents in the receiver above.

In this double form a model of the engine was exhibited to the Royal Society in June 1699, and approved of. The following figure and description are those given in the *Philosophical Transactions*, vol. xxi:—

Fig. 15.



Savary's Model, exhibited before the Royal Society.

“A the furnace, B the boiler, CC two cocks which convey the steam alternately to the vessels DD, which receive the water from the bottom in order to discharge it again at the top. EEEE, valves opening only upwards; FF cocks which keep up the water while the valves on occasion are cleansed; G the force-pipe, H the sucking-pipe, I the water.” The action of this double engine is manifest. One of the vessels (D) is first filled with water from below, by the effect of the vacuum formed in it, and is then discharged into the reservoir above. The steam is then shut off, and the vacuum again begins to form, and this first receiver to refill with water; in the mean time the steam would be unemployed, and therefore it is now admitted into the second receiver D 2, where it forms a vacuum, or if the receiver be filled with water, forces it up to the top, and having emptied it, is again shut off and forms a vacuum to refill this second receiver with water. But in the mean time, this second receiver being now vacuous, and in the process of being refilled with water from below, the steam being unemployed upon it may be admitted to the first receiver D, which has in the interval been charged with water from below, and the steam acting upon it will continue the stream into the reservoir at the top, until the other receiver, D 2, being again filled, is again ready to be discharged in the same direction, and so on as long as the cocks are turned.

Savary's Double Engine, as described in his “Miner's Friend.”

But this working model of the Royal Society was by no means a perfect machine for performing work on a large scale. We have, therefore, extracted the following description of the machine of Savary, in the form which he gave it when introduced for the purpose of draining

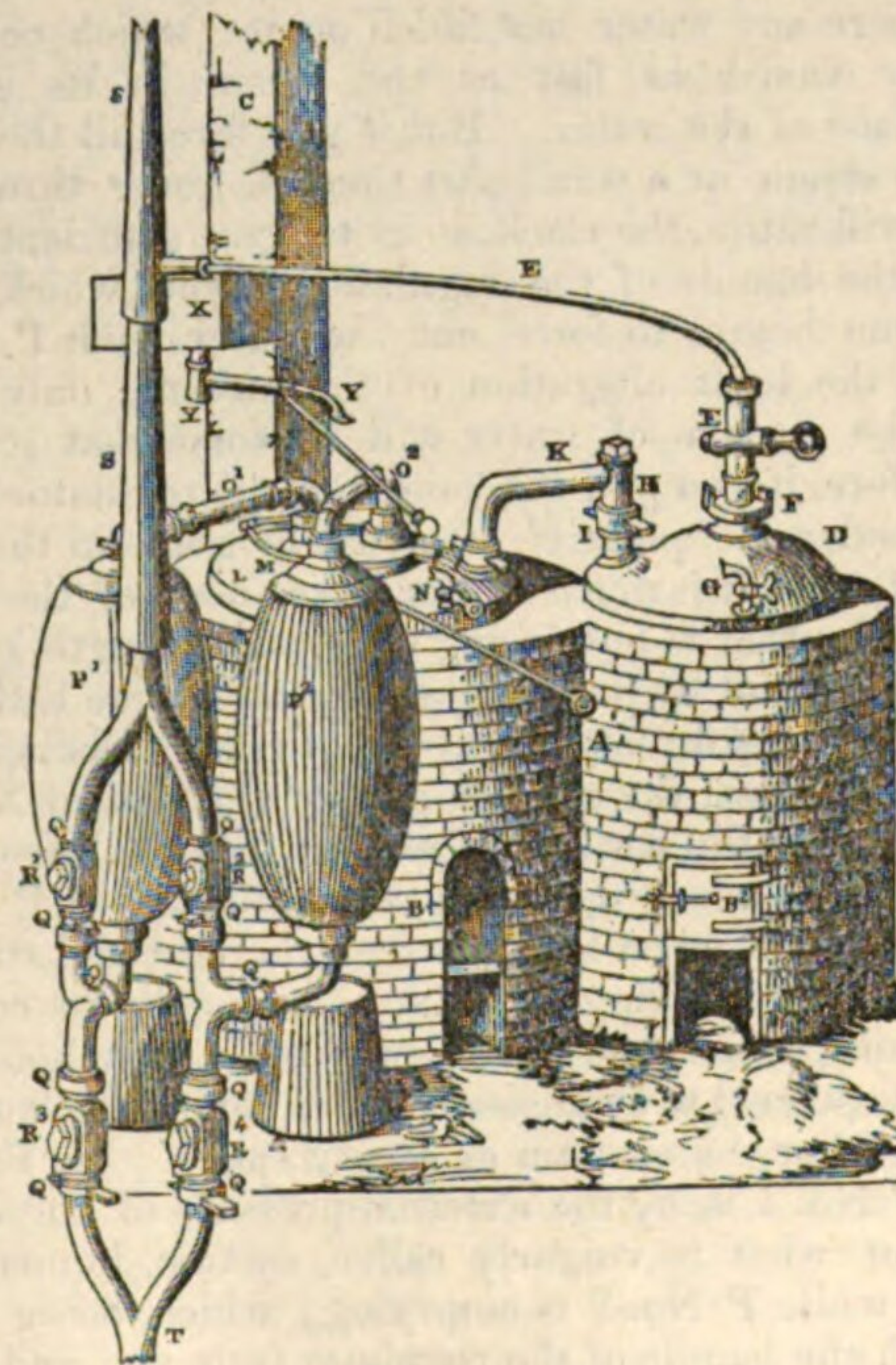
mines. The description and figure are taken from an old work in the Advocates' Library, entitled, “The Miner's Friend; or, a Description of an Engine for Raising Water by Fire, with an Answer to the Objections against it. By Thomas Savary, Gent.” London, 1702.

Fig. 16 represents the engine of Savary as applied to the purpose of drawing water from the bottom of deep mines. The furnaces, boilers, and receivers are placed under ground, on a platform raised sixteen or twenty feet above the level of the water at the bottom of the mine. From this platform the chimney ascends to the surface along the shaft of the mine, and a pipe through which water is forced to the surface accompanies it.

A Description of the Engine.

A the furnaces; B¹ B² the two fireplaces; C the funnel or chimney; D the small boiler; E the pipe and cock of it; F the screw that covers and confines the force; G a small cock going to a pipe within eight inches of its bottom; H a large pipe going the same depth; I a clack on the top of the said pipe opening upwards; K a pipe going from the box of the said clack or valve into the great boiler about an inch into it; L the great boiler; M the screw with the regulator; N a small cock and pipe going half way down the great boiler; O¹ O² steam pipes, one end of each is screwed to the regulator, and the other end to the receivers; P P² the vessels called receivers; Q the screws which bring on the pipes and clacks into the front of the engine; R R R R Nos. 1. 2. 3. 4. valves or clacks of brass, with screws to open and come at them upon occasion; S the force-pipe; T the sucking-pipe, having a square frame of wood, with holes round its bottom in the water; X a cistern, with a buoy-cock coming from the bottom of the said cistern; Z the handle of the regulator.

Fig. 16.



“The manner of working this engine is first: there is a good double furnace so contrived that the flame of the fire may circulate round and encompass the two boilers to the best advantage, as you do coppers for brewing. Before you make any fire, unscrew G and N, being the two small gauge-pipes and cocks belonging to the two boilers, and at the holes fill L, the great boiler, two-thirds full of water, and D, the small boiler, quite full;

Steam-Engine.
Savary's Description of his Steam-Engine.

then screw in the said pipes again, as fast and tight as possible; then light the fire at B, No. 1; when the water in L boils, the handle of the regulator, marked Z, must be thrust off from you as far as it will go, which makes all the steam rising from the water in L press with irresistible force through O No. 1, into P No. 1, making a noise as it goes; and when all is gone out, the bottom of the vessel P No. 1 will be very hot. Then pull the handle of the regulator towards you, by which means you stop O No. 1, and force your steam through O No. 2 into P No. 2, until that vessel has discharged its air through the clack R No. 2 up the force pipe. In the mean time, by the steam's condensing in the vessel P No. 1, a vacuum of emptiness is created, so that the water must and will necessarily rise up through T, the sucking-pipe, lifting up the clack R No. 3, and filling the vessel P No. 1.

"In the mean time, the vessel P No. 2 being emptied of its air, turn the handle of the regulator from you again, and the force is upon the surface of the water in P No. 1; which surface being only heated by the steam, it does not condense it, but the steam gravitates or presses with an elastic quality like air, still increasing its elasticity or spring, till it counterpoises or rather exceeds the weight of the water ascending in S, the forcing pipe, out of which the water in P No. 1 will be immediately discharged, when once gotten to the top; which takes up some time to recover that power, which having once got, and being in work, it is easy for any one that never saw the engine, after half an hour's experience, to keep a constant stream running out the full bore of the pipe S. For on the outside of the vessel P No. 1 you may see how the water goes out, as well as if the vessel was transparent; for as the steam continues within the vessel, so far is the vessel dry without, and so hot, as one is scarce able to endure the least touch with one's hand; but as far as the water is, the said vessel will be cold and wet, where any water has fallen on it; which cold and moisture vanish as fast as the steam in its descent takes place of the water. But if you force all the water out, the steam, or a small part thereof, going through R No. 1, will rattle the clack, so as to give sufficient notice to pull the handle of the regulator to you, which at the same time begins to force out the water from P No. 2, without the least alteration of the stream; only sometimes the stream of water will be somewhat stronger than before, if you pull the handle of the regulator before any considerable quantity of steam be gone up the clack R No. 1; but it is much better to let none of the steam go off, (for that is but losing so much strength,) and is easily prevented by pulling the regulator some little time before the vessel forcing is quite emptied. This being done, immediately turn the cock or pipe of the cistern X on P No. 1, so that the water proceeding from X, through L Y, (which is never open but when turned on P No. 1 or P No. 2, but when between them is tight and stanch;) I say, the water falling on P No. 1 causes by its coolness the steam (which had such great force just before, by its elastic power) to condense—to become, in the language of our author, 'a vacuum or empty space.' So that the vessel P No. 1 is, by the external pressure of the atmosphere, or what is vulgarly called suction, immediately refilled while P No. 2 is emptying; which being done, you push the handle of the regulator from you, and throw the force on P No. 2, causing the steam in that vessel to condense, so that it fills while the other empties. The labour of turning these two parts of that engine, viz. the regulator and water cock, and tending the fire, being no more than what a boy's strength can perform for a day together.

"The ingenious reader will probably here object, that the steam being the cause of this motion and force, and that steam is but water rarefied, the boiler L must be in some

certain time emptied, so as the work of the engine must stop to replenish the boiler, or endanger the burning out or melting the bottom of the boiler.

"To answer which, be pleased to observe the use of the small boiler D, when it is thought fit, by the person tending the engine, to replenish the great boiler, (which requires an hour and a half, or two hours' time to the sinking one foot of water.) Then I say, by turning the cock of the small boiler E, you cut off all communication between S the great force pipe and D the small boiler, by which means D grows immediately hot; by throwing a little fire into B No. 2, the water of which boils, and in a very little time it gains more strength than the great boiler; for the force of the great boiler being perpetually spending and going out, and the other winding up and increasing, it is not long before the force in D exceeds that in L; so that the water in D being depressed in D by its own steam or vapour, must necessarily rise through the pipe K into L, running till the surface of the water in D is equal to the bottom of the pipe H.

"Then the steam and water going together, will, by a noise in the clack I, give sufficient assurance that D has discharged and emptied itself into L, to within eight inches of the bottom. And inasmuch as from the top of D to the bottom of its pipe H is contained about as much water as will replenish one foot; so you may be certain it is replenished one foot—of course then you open the cock I, and refill D immediately.

"By which you will see that there is a constant motion, without fear or danger of disorder or decay; and if you would at any time know if the great boiler L be more than half exhausted, turn the small cock N, whose pipe will deliver water, if the water be above the level of its bottom, which is half way down the boiler; if not, it will deliver steam.

"So likewise will G show you if you have more or less than eight inches of water in D; by which means nothing but a stupid neglect or mischievous design carried on some hours, can any ways hurt the engine. And if a master is suspicious of the design of a servant to do mischief, it is easily discovered by those gauge-pipes. For if he comes when the engine is at work, and finds the surface C of the water in L below the bottom of the gauge-pipe N; or the water in D below the bottom of G, such a servant deserves correction, though three hours after that the working on could not damage or exhaust the boiler. So that, in a word, the clacks being in all water-works always found the better the longer they are used; so here the same effect is found, and all the moving parts of the engine being of like nature, the furnace being made of *Sturbridge* or *Windsor* brick or fire-stone, I don't see it possible for the engine to decay in many years.

"For besides, the clacks, boxes, and water-pipes, regulator and cocks, are all of brass, and the vessels are made of the best hammered copper, of sufficient thickness to sustain the force of the working engine. In short, the engine is so naturally adapted to perform what is required, that even those of the most ordinary and meanest capacity may work it for some years without injury, if not hired or employed by some base person on purpose to destroy it. For after the engine is once fixed and at work, I may modestly affirm that the adventurer or supervisor of the work will be freed from that perpetual charge, expense, and trouble of repairs which many engines are generally liable to."

One of the first uses of Savary's engine, proposed by himself, was to raise water into a reservoir, from which it should be allowed to fall on a mill-wheel, turning round the machinery in the same way as a common fall of water; and after reaching the bottom, it was again to be raised by the steam-engine to the upper reservoir, for the pur-

Steam-Engine.
Savary's Description of his Pumping Steam-Engine.

Savary's Engine used to turn round Machinery.

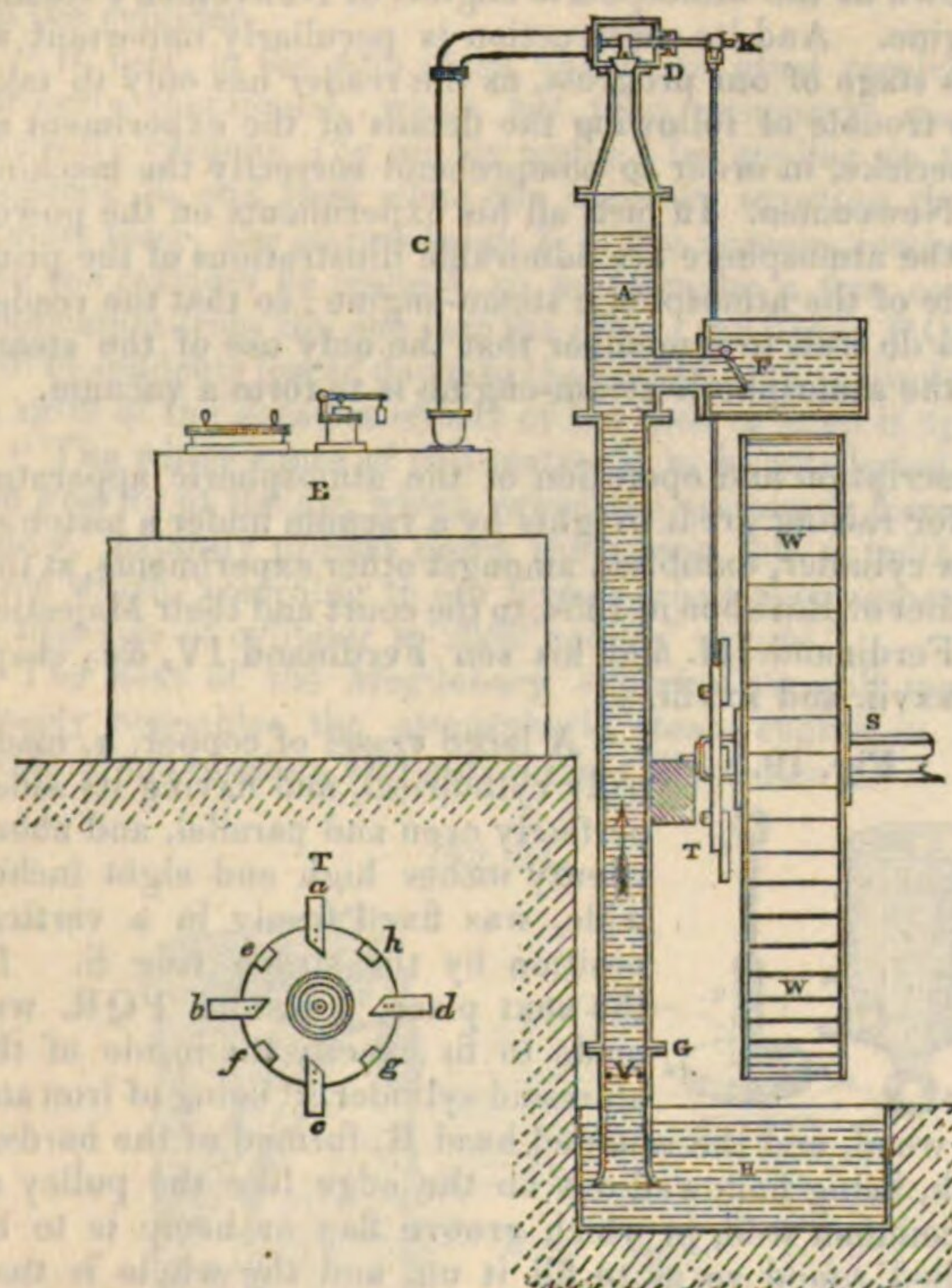
Steam-Engine.

Savary's
Revolving
Steam-En-
gine.

pose of again descending on the wheel. We are not, however, aware that any machine was applied in this manner during Savary's life; but after his death several of them were erected by a Mr Joshua Rigley, at Manchester, and throughout Lancashire, to impel the machinery of some of the earliest cotton-mills and manufactories of the district. One of these, of which we have here given the figure, was erected at St Pancras, London, at the manufactory of a Mr Kier, where it long continued to turn lathes, &c. We have taken the following description of it from Nicholson's Journal.

"The figure is the section of this engine taken through the centre. B represents a boiler shaped like a waggon, seven feet long, five feet wide, and five deep; it was considered as being of dimensions sufficient to work a larger engine; a circumstance which must, in a certain degree, diminish the effects of the present one. The boiler feeds itself with water, from a cistern, elevated by a pipe which descends into the boiler and has a valve in it at the upper end, which shuts downwards, and is connected by a wire with a float on the surface of the water within the boiler, so as to open the valve whenever the water subsides below its intended level; for the float which swims on the water then sinks, and by its weight draws the valve up to allow the water from the cistern to run down the pipe, and supply the deficiency; but as the water in the boiler rises

Fig. 17.



the float closes the valve. The boiler, therefore, remains constantly, or nearly, at the same degree of fullness.

"The steam is conveyed by a pipe C to a box D, through which, by the opening and shutting of a valve, it can be admitted to the cylindrical receiver A. The axis K serves as a key to open and shut the valve, which is a circular plate formed conical on the edge, and fits in a corresponding aperture in the bottom of the box D; H is a cistern from which the engine draws its water, through a vertical suction-pipe, in which a valve G is placed, to prevent the return of the water; F is another cistern, into which the water is delivered from the receiver A, through the spout F, which is provided with a valve

opening outwards; WW represents an overshot water-wheel, 18 feet in diameter, of which the axis S communicates motion to the lathes and other machines used in the manufactory.

"The engine raises the water from the lower cistern H, by suction, into the receiver A, from which it runs into the upper cistern F, and thence flows through a sluice into the buckets of the water-wheel W, to give it motion. The water as it is discharged from the buckets of the wheel falls again into the lower cistern H. As the same water circulates continually in both the cisterns, it becomes warmer than the hand, after working a short time; for which reason the injection-water is forced up by a small forcing pump from a well. This injection-pump is worked by the water-wheel by means of a loaded lever or pump handle, which is raised up by the motion of the wheel, and then left to descend suddenly by its weight and force up the water into the receiver. A leaden pipe passes from this forcing-pump to the upper or conical part of the receiver A, for the purpose of injecting cold water at the proper time. Neither of these could be represented with convenience in the present section.

"The manner in which the steam and cold water are alternately admitted into the receiver A, remains to be explained. Upon the extremity of the axis S of the water-wheel a solid wooden wheel T is fixed; it is about four feet in diameter, and turns round with the water-wheel. It is represented separately, as seen in the front. *a b c d* are four cleats, all or any number of which may be fixed on the wheel at a time. Each cleat has its correspondent block, *e f g h* on the opposite surface of the wheel. The use of these is to work the engine. Thus, suppose the water-wheel and this wheel T, with all the revolving apparatus, are turning round, one of the cleats, *a*, meets in its rotation with a lever, which it lifts up, and this opens the steam-valve D by a rod of communication reaching to the handle of the axis K. The steam consequently passes into the receiver A, and the steam-valve shuts again as soon as the cleat *a* of the wheel T has passed away from the lever by the motion of the wheel. All this time the correspondent block *e* on the other side of the wheel T had been operating to raise up the loaded lever which forms the handle of the forcing-pump. And at the same instant that the steam-valve D is shut, as above mentioned, the block *e* quits the loaded lever, after having raised it up, and leaves it to descend suddenly by its own weight. This depresses the forcer of the pump, and thereby throws a jet of cold water up into the receiver A, and it falls in a shower of drops through the steam which fills the receiver, so as to cool and condense the steam, and make a vacuum therein. The pressure of the atmosphere upon the surface of the water in the cistern H then causes the water to mount up the perpendicular suction-pipe, through the valve G, towards the exhausted receiver.

"When the engine is first set to work, the water-wheel being motionless, the steam-valve and injection-pump are moved by hand; and if the engine has been long out of work, two or three strokes may be necessary to raise the water to the top of the receiver A, so as to fill it full of water. As soon as this is the case, and the steam-valve is opened to admit steam into the receiver, the whole contents of water above the spout and valve F then flows out of the receiver A, by its own gravity, into the upper cistern R.

"The water which is thus raised is suffered to flow from the cistern upon the overshot water-wheel W, through a sluice, and by that means keeps the wheel in motion, and replenishes the lower cistern. There is no reservoir for the injection-water, but the requisite quantity is driven

Steam-Engine.

Savary's
Revolving
Steam-En-
gine.

Steam-Engine.

up at each stroke; and as this is done by the sudden descent of the loaded lever of the pump, the water is injected very suddenly into the receiver."

The Atmospheric Steam-Engine of Newcomen and Cawley.

Atmospheric Steam-Engine.

The title of this steam-engine correctly indicates the principle of its action. The effect which it produces is not by the direct and immediate agency of steam, but of the atmosphere. All that the steam does in this machine is merely to make way for the atmosphere, and give effect to its pressure. It is therefore necessary to retrace our steps, and give some consideration to the mode of operation of atmospheric pressure as an introduction to this description. A full exposition of the nature and laws of the pressure of atmosphere has been given in the article PNEUMATICS, to which our readers are referred for a more perfect acquaintance with this subject. We shall only touch upon such branches of experiment, concerning atmospheric pressure, as are so closely intertwined with our more immediate investigation as to constitute an essential part of it.

Atmospheric experiments of Otto Guericke.

We have merely to notice, that after the discovery of the laws of atmospheric pressure by the pupils of Galileo, we owe most of our information on the phenomena resulting from the pressure of the atmosphere, and of the apparatus constructed for exhibiting its powers on a large scale, to Otto Guericke, privy councillor of his serene highness the Elector of Brandenburg, and consul of Magdeburg, who had in 1654 brought his pneumatic apparatus to considerable perfection, and continued to make his experiments to an advanced age. They were published by Gasparus Schottus in his work "De Arte Mechanica Hydraulica Pneumatica," in 1657, and again by the author himself, in a thin volume, entitled "Ottonis Guericke Experimenta Nova Magdeburgica de Vacuo Spatio, Aeris Pondere," &c. Amstelodami, 1672, fol.

We have extracted and translated the following passages of this rare work from a copy in the library of the College of Physicians at Edinburgh. They show us that the mode of raising water above its level by atmospheric pressure, and by a vacuum, was by him so clearly made known, that the use of steam as the instrument for effecting that vacuum was a very direct and easy transition. Indeed the apparatus we have first to consider is a very simple illustration of the action of Savary's machine.

Raising water by atmospheric pressure into a vacuum.

Illustration of raising water by a vacuum, and the pressure of the atmosphere, taken from chapter xx. of Otto Guericke.

"Make four tubes or pipes *ab, cd, ef, gh*, each about eight feet long, made of glass, and mounted at the extremities with conically tapered fittings, so as to be accurately joined to each other, each joint surrounded by a small cup, into which liquid being poured, the joints may be prevented from taking in air; let there also be a stopcock on the lowest, and let there be taken a glass flask *i*, also fitted air-tight with a stopcock *k*.

"Having joined all these tubes together, so as to form a tube erected on the wall of a house, the lower end being

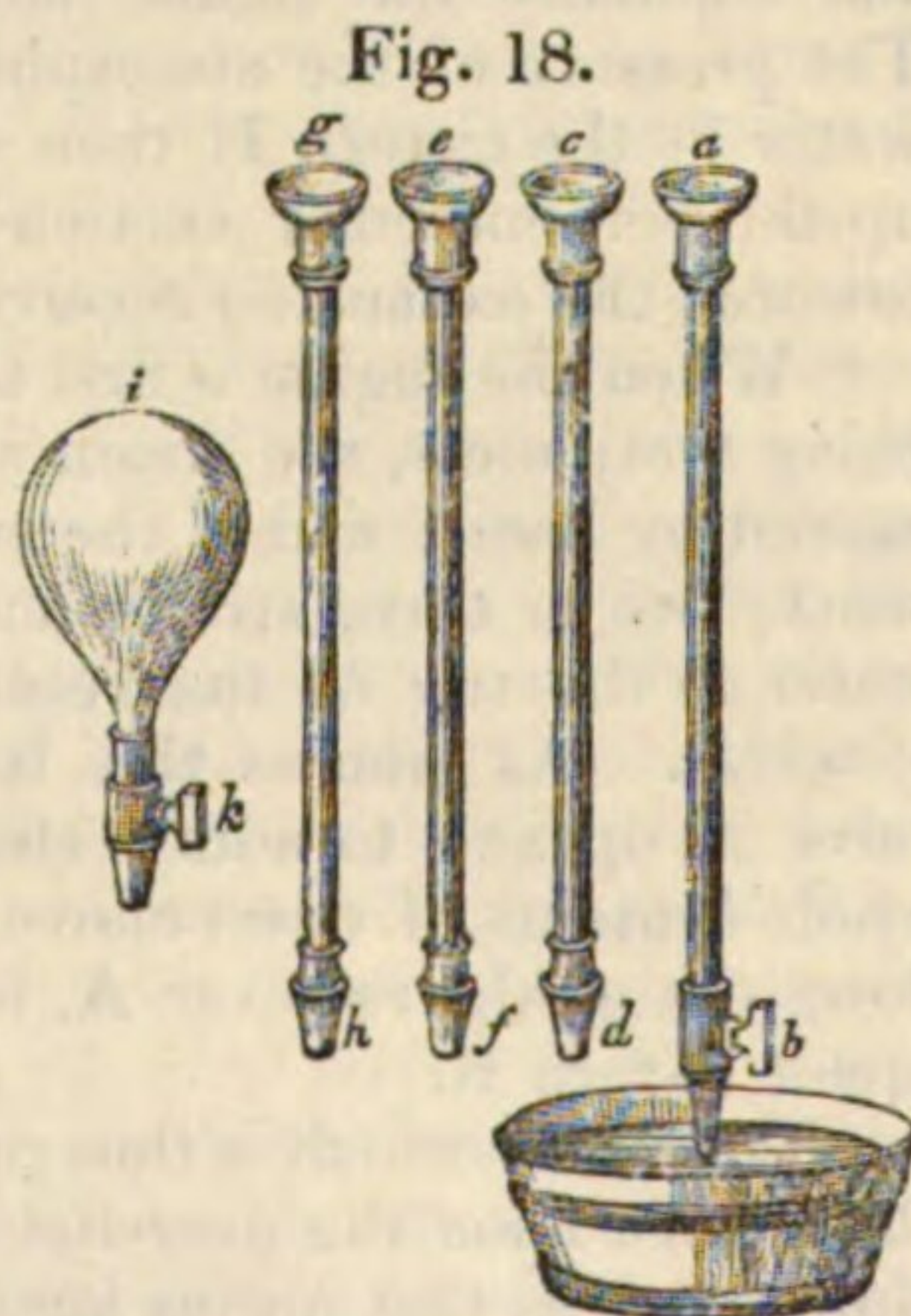


Fig. 18.

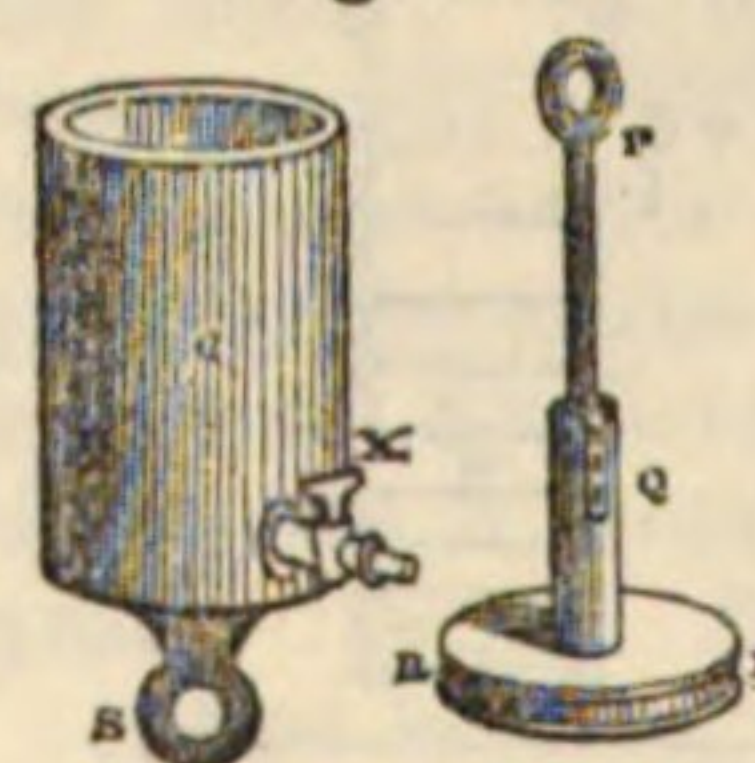
immersed under water in the open vessel; the large flask or receiver having been previously emptied of air by the air-pump, and being now placed on the top of the long tube, and the stopcock *k* being opened, the water will violently rush up the tube to the height of above thirty feet. The rationale is this, that the external air presses on the surface of the water in the bucket, which finds free exit from this force up the vacuous space of the tube, from which the air has been withdrawn, into the flask *i*; and settles at such a height as will balance by the weight of the column of water the weight of the circumambient air."

The reader of this very clear and accurate exposition may easily perceive that when it has once been discovered that water, after having been rarefied by heat into steam, so as to fill a large space, is afterwards condensed by cold, so as to leave a portion of that space vacuous, nothing remains to be done except to make the vacuum of the flask *i* by steam instead of an air-pump, and the machine of Savary is obtained. In fact, the flask *i* of Otto Guericke corresponds accurately to the receiver of Thomas Savary. The reader has only to understand the former, in order to perceive at a glance the action of the latter.

This first experiment of Otto Guericke, therefore, represents with fidelity the principle of Savary's engine for raising water by the formation of a vacuum. Not less beautifully does another experiment of the same philosopher exemplify the principle of the species of engine known as the atmospheric engine, or Newcomen's steam-engine. And its construction is peculiarly important at this stage of our progress, as the reader has only to take the trouble of following the details of the experiment of Guericke, in order to comprehend correctly the machine of Newcomen. In fact, all his experiments on the power of the atmosphere are admirable illustrations of the principle of the atmospheric steam-engine; so that the reader will do well to remember that the only use of the steam in the atmospheric steam-engine is to form a vacuum.

Description and operation of the atmospheric apparatus for raising great weights by a vacuum under a piston in a cylinder, exhibited amongst other experiments, at the diet of Ratisbon in 1654, to the court and their Majesties Ferdinand III. and his son Ferdinand IV, &c., chap. xxvii. and xxviii.

Fig. 19.



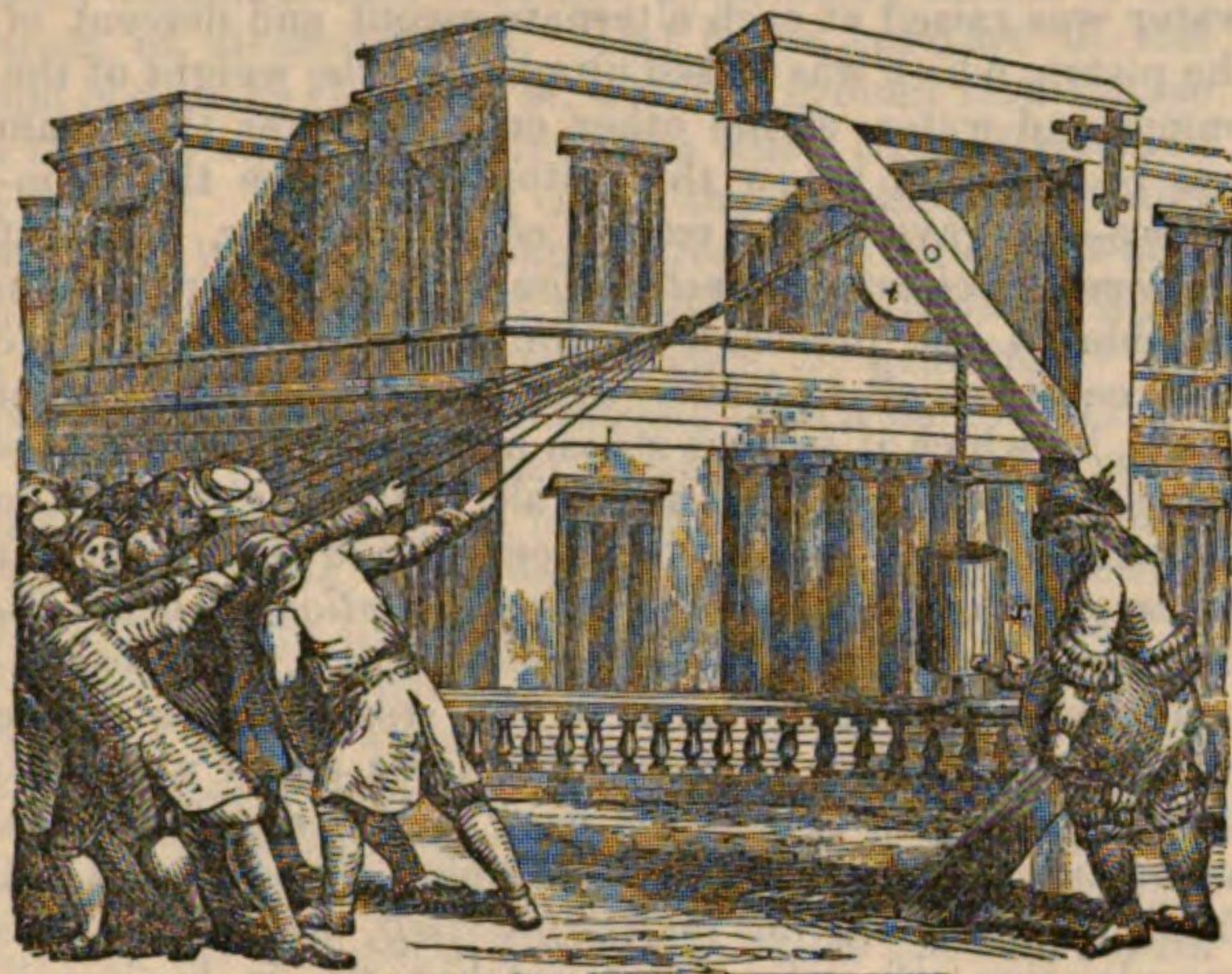
"A large vessel of copper, *a*, made truly cylindrical, and having its sides perfectly even and parallel, and about twenty inches high and eight inches wide, was fixed firmly in a vertical position by the strong ring *S*. In the next place, a piston, *PQR*, was made to fit exactly the inside of the aforesaid cylinder, *P* being of iron and *Q* wood, and the rounded head *R*, formed of the hardest oak, being hollowed out on the edge like the pulley of a common well, in which groove flax or hemp is to be rolled round so as to fill it up, and the whole is then to be placed in the aforesaid cylinder *a*, (like as a piston and its head in a common syringe or pump for extinguishing fires,) and fitted so exactly that air can neither pass outwards or inwards through between the piston and cylinder. Thirdly, the cylinder *a* is to be attached to the great upright beam, Fig. 20, by an iron bracket, through the ring aforesaid *S*, and the piston *PQR* is to be let into the cylinder *a*, and the iron handle *PQ* of the piston is to be passed through the ring of a second iron arm *O*, in such a manner that it can play freely up and down through the whole height of the cylinder, and at the same time be steadily preserved in the straight line, but not permitted to rise further than *O*. In the fourth place, a rope, to the end of which is firmly attached

Steam Engine.

Steam-Engine.
Otto Guericke's experiments on atmospheric pressure.

a hook, is carried round the wheel *t*, and fastened by its hook to the piston rod PQ, and the other end of the rope has other ropes attached to it, to be grasped by the men, as in the figure.

Fig. 20.



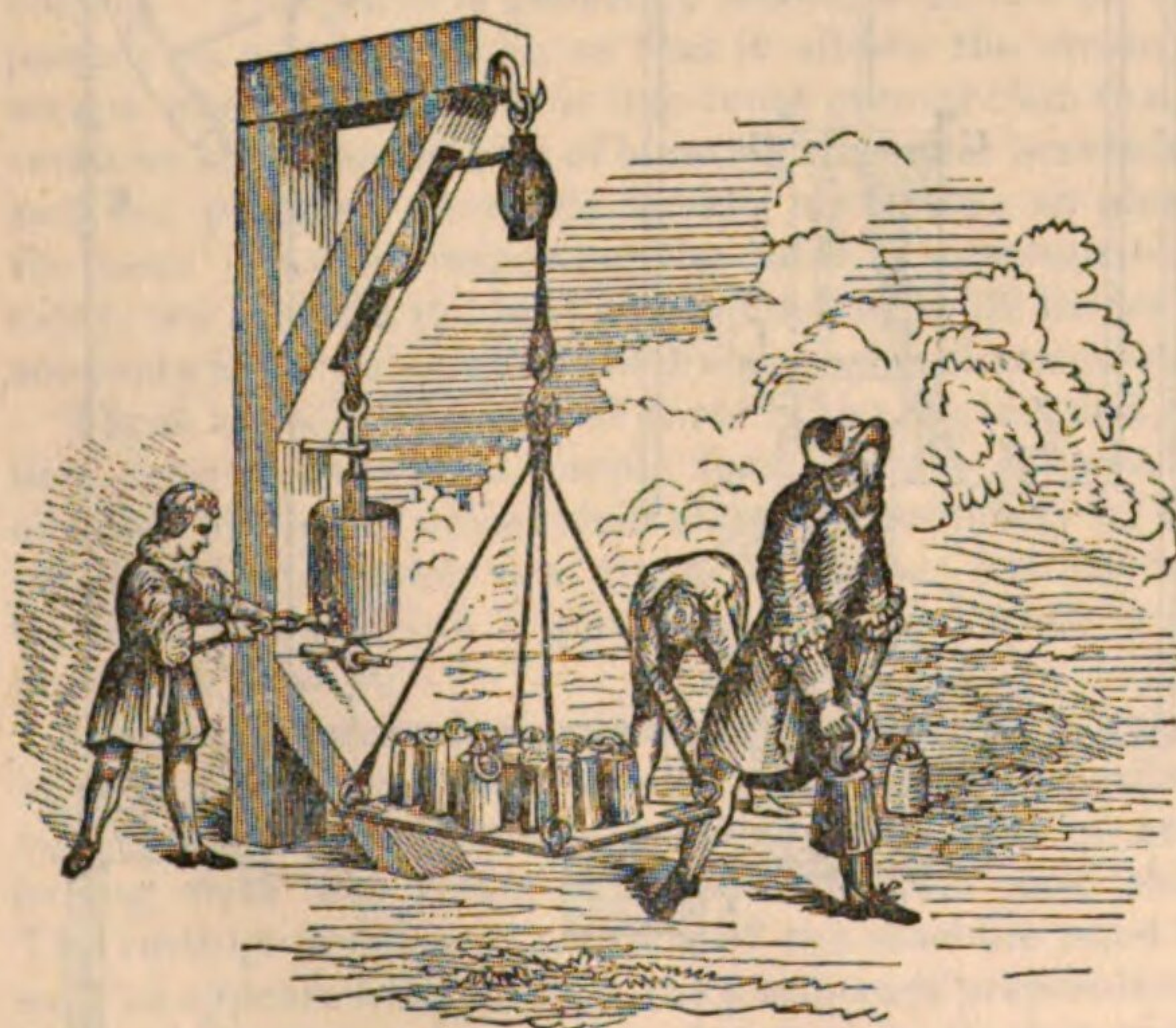
"Now, if the stopcock X be closed, the piston being nearly at the bottom, the joint efforts of fifty or more men will not be able to raise it more than about half way up the cylinder.

"If, now, in the *fifth* place, the large glass receiver, formerly mentioned, which has been previously made perfectly vacuous, (by an air-pump,) be applied to the stopcock X, and then when the men are exerting their utmost force, the stopcocks at X of the vacuous receiver and the cylinder be opened, so as to make a free communication from the one into the other; the piston PQR will be suddenly forced down to the bottom of the cylinders in spite of the greatest efforts of the men to keep it up.

"The whole cause of this matter is to be attributed to the gravity of the air, which, when the vacuum is formed below, instantly presses down the piston into it with a force which, according to our former calculation, amounts in that size of cylinder to 2686 pounds' weight."

The next of the Magdeburg experiments still more closely resembles the atmospheric steam-engine in its mode of application, and still further illustrates it.

Fig. 21.

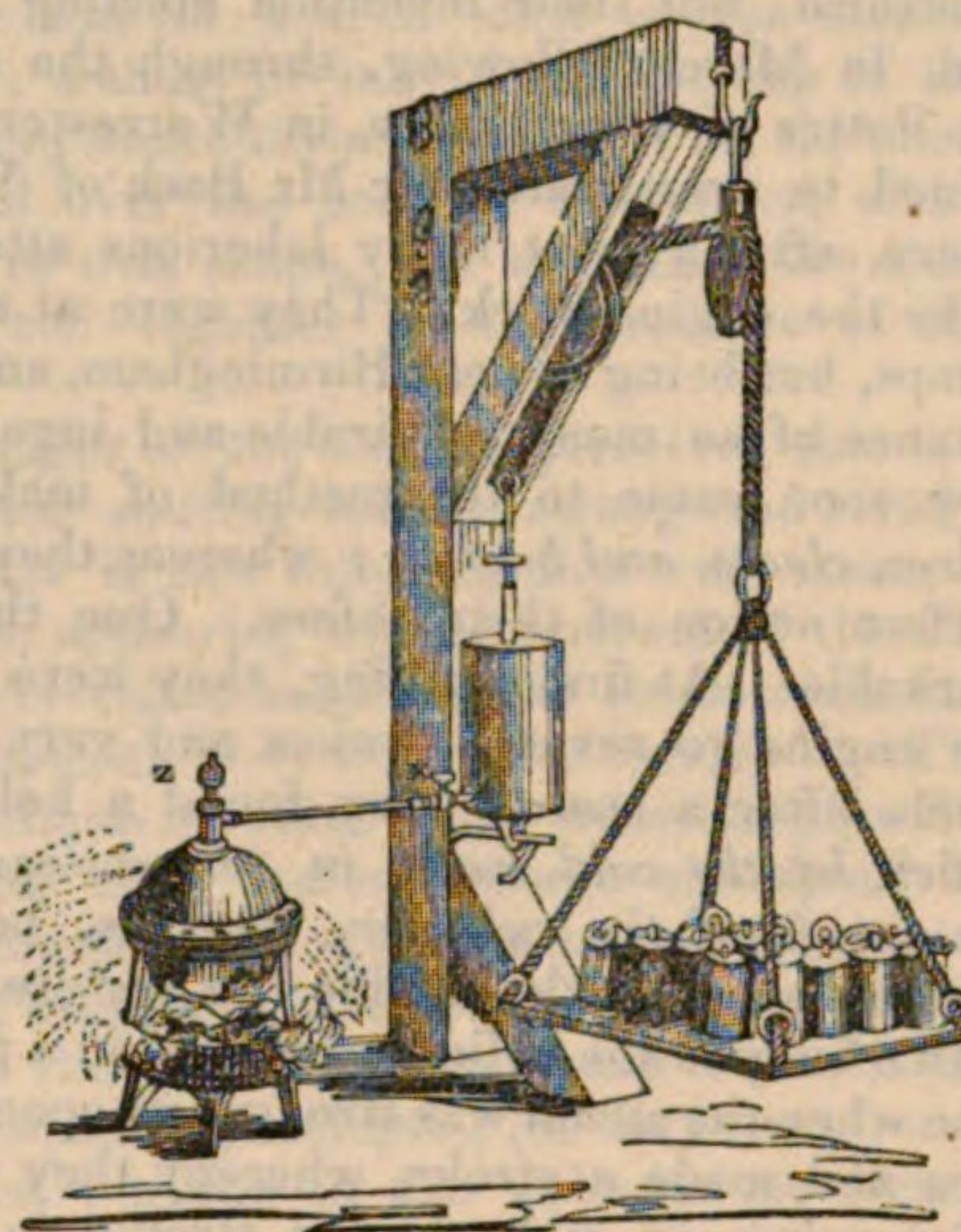


"By the above-mentioned invention, a child of twelve or fifteen years old can raise an enormous weight. Every

thing being left as formerly, only the piston being nearly at the top of the cylinder *a*, you are to pass the rope round a second pulley, hung from a staple; and by a hook to suspend from the rope the scale of a large balance, which you are to load with a weight of 2686 pounds. If a small syringe be applied by a little boy to the stopcock X to pump out the air, it will follow that, as the air is pumped out from below the piston, the atmosphere above will press it down and raise the weight."

The transition from this to the engine of Newcomen is immediate. To the last-described apparatus of Guericke let there be added a small copper globe or boiler, Z, Fig. 22, to be placed over a fire till the water which it contains boils into steam. This steam, entering below the piston, will occupy the whole space of the cylinder; but if now the stopcock X be suddenly closed, and especially if cold water be sprinkled on the outside of it to cool it, the steam will be condensed back

Fig. 22.



into its original bulk of water, and leave the space it formerly occupied in the cylinder a vacuum, into which the atmosphere will press down the piston PQR, just as in the former instance, raising up the weights at the other end of the rope. This is just the atmospheric engine of Newcomen. It is the atmosphere which does the work; the steam acts indirectly as the medium through which a vacuum is effected; and it is only the efficient agency of the atmosphere which is thus rendered useful in giving motion to a weight.

We hope that nothing which we have here said concerning the discoveries of Guericke will be misunderstood, as intended in any way to depreciate the value set upon the inventions of Mr Savary or Mr Newcomen; they are only introduced as illustrations by which we are most easily conducted to a thorough comprehension of the principles on which they act, and of the state of knowledge of atmospheric pressure which existed at that date. The experimental apparatus of Guericke was in no respect a steam-engine; and although his speculations were divulged before the inventions of Savary and Newcomen, the agency of steam still remained to be introduced, before a machine useful to the arts and industry of man was produced.

Newcomen's Fire-Engine.—Switzer, in his *Hydrostatics*, Newcomen's atmospheric steam-engine described by Switzer, (1729) has the following passage:—"To finish this long account of the surprising engine for the raising of water by fire, I produce this last improvement of it by Mr Thomas Newcomen, which makes it undoubtedly the beautifullest and most useful engine that any age or country ever yet produced, as the best and most useful inventions and improvements which have been discovered either in art or nature, have, in process of time, been liable to improvement, so this, of the fire-engine, has been subject to the same, for this ingenious gentleman to whom we owe this late invention, has, with a great deal of modesty, but as much judgment, given the finishing

Steam-Engine.
Atmospheric pressure applied by using steam to form a vacuum.

Atmospheric steam-engine.

Steam-Engine.

Desaguliers's account of improvements of Newcomen's engine.

stroke to it. It is, indeed, generally said to be an improvement to Mr Savary's engine; but I am well informed, that *Mr Newcomen was as early in his invention as Mr Savary was in his*, only the latter being nearer the court, had obtained his patent before the other knew it, on which account Mr Newcomen was glad to come in as a partner to it." Dr Desaguliers speaking of Savary's engine also says, "these discouragements (the difficulty of making sufficient high-pressure boilers, &c.) stopped the progress and improvement of this engine till Mr Newcomen, an ironmonger, and John Cawley, a glazier living at Dartmouth, brought it to the present form in which it is now used and has been near these thirty years." (1744.) *Experimental Philosophy*, ii. 467. And again, "about the year 1710, Thomas Newcomen, ironmonger, and John Cawley, glazier, of Dartmouth, in the county of Southampton, (Anabaptists,) made then several experiments in private, and having brought it to work with a piston, &c., in the latter end of the year

A.D.1711. 1711, made proposals to draw the water at Griff in Warwickshire; but their invention meeting with no reception, in March following, through the acquaintance of

A.D.1712. Mr Potter of Bromsgrove, in Worcestershire, they bargained to draw water for Mr Back of Wolverhampton, where, after a great many laborious attempts, they did make the engine work. They were at a loss about the pumps, but being so near Birmingham, and having the assistance of so many admirable and ingenious workmen, they soon came to the method of making the *pump-valves, clacks, and buckets*; whereas they had but an imperfect notion of them before. One thing is very remarkable. At first working, they were surprised to see the engine go several strokes and very quick together, when, after a search, they found a hole in the piston which *let the cold water in to condense the steam in the inside of the cylinder*, whereas, before, they had always done it on the outside. They used before to work with a buoy in the cylinder inclosed in a pipe, which buoy rose when the steam was strong, and opened the injection-pipe and made a stroke, whereby they were capable of only giving six, eight, or ten strokes in a minute, till a boy named Humphrey Potter, who attended the engine, added what he called *scoggan*, by which the beam of the

A.D.1713. engine always opened and shut its own valves, and then it would go (entirely without the attendance of a man) fifteen or sixteen strokes in a minute. But this being perplexed with catches and strings, Mr Henry Beighton, in an

A.D.1718. engine he had built at Newcastle-on-Tyne in 1718, took them all away, the beam itself supplying all much better. The way of leathering the piston was found by accident about 1713. Having screwed a large broad piece of leather to the piston, which turned up the sides of the cylinder two or three inches: in working it wore through, and cut that piece from the other, which, falling flat on the piston, wrought with its edge to the cylinder, and having been in a long time, was worn very narrow, which being taken out, they had the happy discovery whereby they found that a *bridle rein or even a soft thick piece of rope or match going round, would make the piston air and water tight.*"

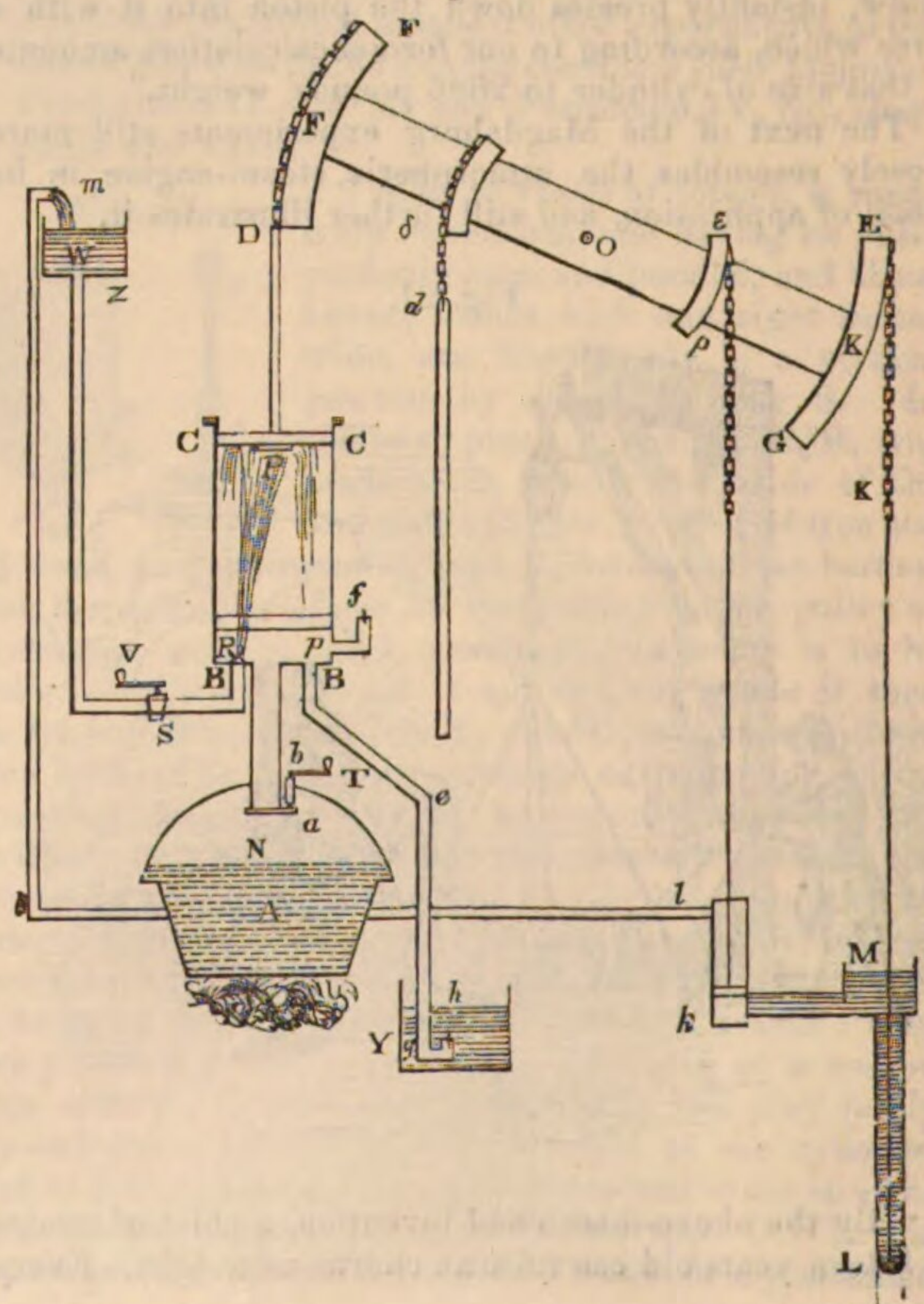
Summary of the history of the atmospheric steam-engine. This short note of Dr Desaguliers, who, with Switzer, is our authority for the historical facts of this date, contains the leading points of the history of the steam-engine as generally used for raising water during the eighteenth century. Newcomen gave to the engine a cylinder and piston: he formed a vacuum in the cylinder below the piston, by first admitting steam from the boiler so as to expel air and balance the pressure of the atmosphere, and afterwards condensing the steam so as to reduce it back to its primitive bulk of water, and thus, by leaving the space below the piston empty, allow the pressure of the atmosphere upon the whole surface of the

piston to carry it with a force somewhat less than fourteen pounds on each inch of that surface downwards to the bottom of the cylinder, so that by suspending the piston with a chain from the end of a rocking beam to the opposite extremity of which the rod and buckets of a large draining-pump were attached, a considerable volume of water was raised at each alternate ascent and descent of the piston, which was raised up again by the weight of the pumps and water, at the other end, whenever the steam was re-admitted below the piston to balance the atmosphere—he gave to the valves, clacks, buckets, &c., that improved mechanical construction which rendered them suitable to the precision of the action of steam. He first constructed a piston with an elastic packing of hemp, by which it is kept steam and air-tight as it moves along the cylinder; and, above all, availed himself of the experience of an unlucky accident to add the important process in the steam-engine of condensation of steam by injection of cold water directly amongst it. All these inventions of Newcomen give to the steam-engine of the present day its most important features; and if we add to these the scoggan or sculking gear of Potter, by which the attendant of the engine was enabled to scog or sculk from his work, leaving the engine itself, by an ingenious complication of strings and catches to do his work, opening and shutting its own valves, with much greater precision, quickness, and regularity, than the listless attendant had ever exercised or even the very closest attention could attain; and if, further, we include the ingenious and more permanent mechanism which Beighton introduced as a substitution for the rude expedients of strings and straps; and, finally, if we include the admirable proportions and constructions, and adaptations of all the various parts of the engine to each other, and to the boilers and furnaces, and of these to the nature of the work to be done, as displayed in the magnificent atmospheric engines of the sagacious and philosophical Smeaton, we shall comprehend, in this succinct view, all that had been done for the steam-engine previously to the time of Watt.

Steam-Engine.

Summary of the history of the Atmospheric Steam-Engine.

Fig. 23.



Steam-Engine.

Dr Robison's description and explanation of Newcomen's engine.

The following is Dr Robison's description and explanation of Newcomen's engine:—

Let A (fig. 23) represent a great boiler properly built in a furnace. At a small height above it is a cylinder CBBC of metal, bored very truly and smoothly. The boiler communicates with this cylinder by means of the throat or steam-pipe N. The lower aperture of this pipe is shut by the plate N, which is ground very flat, so as to apply very accurately to the whole circumference of the orifice. The plate is called the regulator or steam-cock, and it turns horizontally round an axis *ba* which passes through the top of the boiler, and is nicely fitted to the socket, like the key of a cock, by grinding. The upper end of this axis is furnished with a handle *bT*.

A piston P is suspended in this cylinder, and made air-tight by a packing of leather or soft rope, well filled with tallow; and, for greater security, a small quantity of water is kept above the piston. The piston-rod PD is suspended by a chain, which is fixed to the upper extremity F of the arched head FD of the great lever or working beam FK, which turns on the gudgeon O. There is a similar arched head EG at the other end of the beam. To its upper extremity E is fixed a chain carrying the pump-rod KL, which raises the water from the mine. The load on this end of the beam is made to exceed considerably the weight of the piston P at the other extremity.

At some small height above the top of the cylinder is a cistern W called the injection cistern. From this descends the injection-pipe ZSR, which enters the cylinder through its bottom, and terminates in a small hole R, or sometimes in a nozzle pierced with many smaller holes diverging from a centre in all directions. This pipe has at S a cock called the injection-cock, fitted with a handle V.

At the opposite side of the cylinder, a little above its bottom, there is a lateral pipe, turning upwards at the extremity, and there covered by a clack-valve *f*, called the snifting valve, which has a little dish round it to hold water for keeping it air-tight.

There proceeds also from the bottom of the cylinder a pipe *pegh*, (passing behind the boiler,) of which the lower end is turned upwards, and is covered with a valve *h*. This part is immersed in a cistern of water Y, called the hot well, and the pipe itself is called the eduction-pipe. Lastly, the boiler is furnished with a safety-valve called the puppet-clack, (which, for want of room, is not represented in this sketch,) in the same manner as Savary's engine. This valve is generally loaded with one or two pounds on a square inch; so that it allows the steam to escape when its elasticity is one-tenth greater than that of common air. Thus all risk of bursting the boiler is avoided, and the pressure outwards is very moderate; so also is the heat. For, by inspecting the table of vaporous elasticity, we see that the heat corresponding to 32 inches of elasticity is only about 216° of Fahrenheit's thermometer.

These are all the essential parts of the engine, and are here drawn in the most simple form, till our knowledge of their particular offices shall show the propriety of the peculiar forms which are given to them. Let us now see how the machine is put in motion, and what is the nature of its work.

The water in the boiler being supposed to be in a state of strong ebullition, and the steam issuing by the safety-valve, let us consider the machine in a state of rest, having both the steam-cock and injection-cock shut. The resting position or attitude of the machine must be such as appears in the sketch, the pump-rods preponderating, and the great piston being drawn up to the top of the cylinder. Now open the steam-cock by turning the handle T of the regulator. The steam from the boiler will immediately rush in, and flying all over the cylinder, will mix with the air. Much of it will be condensed by

the cold surface of the cylinder and piston, and the water produced from it will trickle down the sides, and run off by the eduction-pipe. This condensation and waste of steam will continue till the whole cylinder and piston are made as hot as boiling water. When this happens, the steam will begin to open the snifting-valve *f*, and issue through the pipe; slowly at first, and very cloudy, being mixed with much air. The blast at *f* will grow stronger by degrees, and more transparent, having already carried off the greatest part of the common air which filled the cylinder. We supposed that the water was boiling briskly, so that the steam was issuing by the safety-valve which is in the top of the boiler, and through every crevice. The opening of the steam-cock puts an end to this at once, and it has sometimes happened that the cold cylinder abstracts the steam from the boiler with such astonishing rapidity, that the pressure of the atmosphere has burst up the bottom of the boiler. We may here mention an accident of which we were witnesses, which also shows the immense rapidity of the condensation. The boiler was in a frail shed at the side of the engine-house; a shoot of snow from the top of the house fell down and broke through the roof of the shed, and was scattered over the head of the boiler, which was of an oblong or oval shape. In an instant the sides of it were squeezed together by the pressure of the atmosphere.

When the manager of the engine perceives that not only the blast at the snifting-valve is strong and steady, but that the boiler is now fully supplied with steam of a proper strength, appearing by the renewal of the discharge at the safety-valve, he shuts the steam-cock, and opens the injection-cock S by turning its handle V. The pressure of the column of water in the injection-pipe ZS, immediately forces some water through the spout R. This coming in contact with the pure vapour which now fills the cylinder, condenses it, and thus makes a partial void, into which the more distant steam immediately expands, and by expanding collapses, (as has been already observed.) What remains in the cylinder no longer balances the atmospherical pressure on the surface of the water in the injection-cistern, and therefore the water spouts rapidly through the hole R, by the joint action of the column ZS, and the unbalanced pressure of the atmosphere; at the same time the snifting-valve *f*, and the eduction-valve *h*, are shut by the unbalanced pressure of the atmosphere. The velocity of the injection water must therefore rapidly increase, and the jet will dash (if single,) against the bottom of the piston, and be scattered through the whole capacity of the cylinder. In a very short space of time, therefore, the condensation of the steam becomes universal, and the elasticity of what remains is almost nothing. The whole pressure of the atmosphere is exerted on the upper surface of the piston, while there is hardly any on its under side. Therefore, if the load on the outer end E of the working-beam be inferior to this pressure, it must yield to it. The piston P must descend, and the pump-piston L, must ascend, bringing along with it the water of the mine, and the motion must continue till the great piston reaches the bottom of the cylinder; for it is not like the motion which would take place in a cylinder of air rarefied to the same degree. In this last case, the impelling force would be continually diminished, because the capacity of the cylinder is diminished by the descent of the piston, and the air in it is continually becoming more dense and elastic. The piston would stop at a certain height, where the elasticity of the included air, together with the load at E, would balance the atmospherical pressure on the piston. But when the contents of the cylinder are pure vapour, and the continued stream of injected cold water keeps down its temperature to the same pitch as at the beginning, the elasticity of the remaining steam can never increase by

Steam-Engine.

How the machine is put in motion, and the nature of the work.

Steam-Engine.

the descent of the piston, nor exceed what corresponds to this temperature. The impelling or accelerating force therefore remains the same, and the descent of the piston will be uniformly accelerated, if there be not an increase of resistance arising from the nature of the work performed by the other end of the beam. This circumstance will come under consideration afterwards, and we need not attend to it at present. It is enough for our present purpose to see, that if the cylinder have been completely purged of common air before the steam-cock was shut, and if none have entered since, the piston will descend to the very bottom of the cylinder. And this may be frequently observed in a good steam-engine, where every part is air-tight. It sometimes happens, by the pit-pump drawing air, or some part of the communication between the two strains giving way, that the piston comes down with such violence as to knock out the bottom of the cylinder with the blow.

The piston does not begin to descend the moment the injection is made.

The only observation which remains to be made on the motion of the piston in descending is, that it does not begin at the instant the injection is made. The piston was kept at the top by the preponderancy of the outer end of the working-beam, and it must remain there till the difference between the elasticity of the steam below it and the pressure of the atmosphere exceed this preponderancy. There must, therefore, be a small space of time between the beginning of the condensation and the beginning of the motion. This is very small, not exceeding the third or the fourth part of a second; but it may be very distinctly observed by an attentive spectator. He will see, that the instant the injection-cock is opened, the cylinder will sensibly rise upwards a little by the pressure of the air on its bottom. Its whole weight is not nearly equal to this pressure; and instead of its being necessary to *support* it by a strong floor, we must *keep it down* by strong joists loaded by heavy walls. It is usual to frame these joints into the posts which carry the axis of the working-beam, and are therefore loaded with the whole strain of the machine. This rising of the cylinder shows the instantaneous commencement of the condensation; and it is not till *after* this has been distinctly observed, that the piston is seen to start, and begin to descend.

The circumstances that succeed the descent of the piston.

When the manager sees the piston as low as he thinks proper, he shuts the injection-cock, and opens the steam-cock. The steam has been accumulating above the water in the boiler during the whole time of the piston's descent, and is now rushing violently through the puppet clack. The moment, therefore, that the steam-cock is opened, it rushes violently into the cylinder, having an elasticity greater than that of the air. It therefore immediately blows open the snifting valve, and allows (at least) the water which had come in by the former injection, and what arose from the condensed steam, to descend by its own weight through the eduction-pipe *d e g h*, to open the valve *h*, and to run out into the hot well. And we must easily see that this water is boiling hot; for while lying in the bottom of the cylinder, it will condense steam till it acquire this temperature, and therefore cannot run down till it condenses no more. There is still a waste of steam at its first admission, in order to heat the inside of the cylinder and the injected water to the boiling temperature; but the space being small, and the whole being already very warm, this is very soon done; and when things are properly constructed, little more steam is wasted than what will warm the cylinder; for the eduction-pipe receives the injection water even during the descent of the piston, and it is therefore removed pretty much out of the way of the steam.

This first puff of the entering steam is of great service: it drives out of the cylinder the vapour which it finds there. This is seldom pure watery vapour: all water

contains a quantity of air in a state of chemical union. The union is but feeble, and a boiling heat is sufficient for disengaging the greatest part of it by increasing its elasticity. It may also be disengaged by simply removing the external pressure of the atmosphere. This is clearly seen when we expose a glass of water in an exhausted receiver. Therefore the small space below the piston contains watery vapour mixed with all the air which had been disengaged from the water in the boiler by ebullition, and all that was separated from the injection water by the diminution of external pressure. All this is blown out of the cylinder by the first puff of steam. We may observe in this place, that waters differ exceedingly in the quantity of air which they hold in a state of solution. All spring-water contains much of it: and water newly brought up from deep mines contains a great deal more, because the solution was aided in these situations by great pressures. Such waters sparkle when poured into a glass. It is therefore of great consequence to the good performance of a steam-engine to use water containing little air, both in the boiler and in the injection cistern. The water of running brooks is preferable to all others, and the freer it is from any saline impregnation it generally contains the less air. Such engines as are so unfortunately situated that they are obliged to employ the very water which they have brought up from great depths, are found greatly inferior in their performance to others. The air collected below the piston greatly diminishes the accelerating force, and the expulsion of such a quantity requires a long-continued blast of the best steam at the beginning of every stroke. It is advisable to keep such water in a large shallow pond for a long while before using it.

Steam-Engine.

Effects of the first puff of entering steam.

Of great consequence to the good performance of a steam-engine, that the water employed contain little air.

Let us now consider the state of the piston. It is evident that it will start, or begin to rise, the moment the steam-cock is opened; for at that instant the excess of atmospherical pressure, by which it was kept down in opposition to the preponderancy of the outer end of the beam, is diminished. The piston is therefore *dragged* upwards, and it will rise even although the steam which is admitted be not so elastic as common air. Suppose the mercury in the barometer to stand at 30 inches, and that the preponderancy at the outer end of the beam is $\frac{1}{9}$ th of the pressure of the air on the piston, the piston will not rise if the elasticity of the steam be not equal to $30 - \frac{30}{9}$, that is, 26.7 inches nearly; but if it be just this quantity, the piston will rise as fast as this steam can be supplied through the steam-pipe, and the velocity of its ascent depends entirely on the velocity of this supply. This observation is of great importance; and it does not seem to have occurred to the mathematicians, who have paid most attention to the mechanism of the motion of this engine. In the mean time, we may clearly see that the entry of the steam depends chiefly on the counter-weight at E: for suppose there was none, steam no stronger than air would not enter the cylinder at all; and if the steam be stronger, it will enter only by the excess of its strength. Writers on the steam-engine (and even some of great reputation) familiarly speak of the steam giving the piston a push; but this is scarcely possible. During the rise of the piston the snifting valve is never observed to blow; and we have not heard any well-attested accounts of the piston-chains ever being slackened by the upward pressure of the steam, even at the very beginning of the stroke. During the rising of the piston the steam is, (according to the common conception and manner of speaking,) *sucked in*, in the same way that air is sucked into a common syringe or pump when we draw up the piston; for in the steam-engine the piston is really drawn up by the counter-weight. But it is still more sucked in, and requires a more copious supply, for another reason. As the piston descended only in consequence of the inside

How the piston rises.

Steam-Engine.

of the cylinder's being sufficiently cooled to condense the steam, this cooled surface must again be presented to the steam during the rise of the piston, and must condense the steam a second time. The piston cannot rise another inch till the part of the cylinder which the piston has already quitted has been warmed up to the boiling point, and steam must be expended in this warming. The inner surface of the cylinder is not only of the heat of boiling water while the piston rises, but is also perfectly dry; for the film of water left on it by the ascending piston must be completely evaporated, otherwise it will be condensing steam. That the quantity thus wasted is considerable, appears by the experiments of Mr Beighton. He found that five pints of water were boiled off in a minute, and produced 16 strokes of an engine whose cylinder contained 113 gallons of 282 inches each; and he thence concluded that steam was 2886 times rarer than water. But in no experiment made with scrupulous care on the expansion of boiling water does it appear that the density of steam exceeds $\frac{1}{10000}$ th of the density of water. Desaguliers says that it is above 14,000 times rarer than water. We have frequently attempted to measure the weight of steam which filled a very light vessel which held 12,600 grains of water, and found it always less than one grain; so that we have no doubt of its being much more than 10,000 times rarer than water. This being the case, we may safely suppose that the number of gallons of steam, instead of being 16 times 113, were nearly five times as much; and that only $\frac{1}{5}$ was employed in allowing the piston to rise, and the remaining $\frac{4}{5}$ ths were employed to warm the cylinder. But no distinct experiment shows so great an expansion of water when converted into steam at 212°. Mr Watt never found it, under the pressure of the air, more than 1800 times rarer than water.

Its ascent chiefly owing to the weight of the pit piston-rods.

The moving force during the ascent of the piston must be considered as resulting chiefly, if not solely, from the preponderating weight of the pit piston-rods. The office of this is to return the steam-piston to the top of the cylinder, where it may again be pressed down by the air, and make another working stroke by raising the pump-rods. But the counter-weight at E has another service to perform in this use of the engine; namely, to return the pump pistons into their places at the bottom of their respective working barrels, in order that they also may make a working stroke. This requires force independent of the friction and inertia of the moving parts; for each piston must be pushed down through the water in the barrel, which must rise through the piston with a velocity whose proportion to the velocity of the piston is the same with that of the bulk of the piston to the bulk of the perforation through which the water rises through the piston. It is enough at present to mention this in general terms: we shall consider it more particularly afterwards, when we come to calculate the performance of the engine, and to deduce from our acquired knowledge, maxims of construction and improvement.

The ascent of the piston differs greatly from the descent.

From this general consideration of the ascent of the piston, we may see that that motion differs greatly from the descent. It can hardly be supposed to accelerate, even if the steam in the cylinder were in a moment annihilated. For the resistance to the descent of the piston is the same with the weight of the column of water, which would cause it to flow through the box of the pump piston with the velocity with which it really rises through it, and must therefore increase as the square of that velocity increases; that is, as the square of the velocity of the piston increases. Independent of friction, therefore, the velocity of descent through the water must soon become a maximum, and the motion become uniform. We shall see by and by, that in such a pump as is generally used, this will happen in less than the 10th part of

a second. The friction of the pump will diminish this velocity a little, and retard the time of its attaining uniformity. But, on the other hand, the supply of steam which is necessary for this motion, being susceptible of no acceleration from its previous motion, and depending entirely on the briskness of the ebullition, an almost instantaneous stop is put to acceleration.

Accordingly, any person who observes with attention the working of a steam-engine, will see that the rise of the piston and descent of the piston-rods is extremely uniform, whereas the working stroke is very sensibly accelerated. Before quitting this part of the subject, and lest it should afterwards escape our recollection, we may observe, that the counter-weight is different during the two motions of the pump-rods. While the machine is making a working stroke, it is lifting not only the column of water in the pump, but the absolute weight of the pistons and piston-rods also; but while the pump-rods are descending, there is a diminution of the counter-weight by the whole weight lost by the immersion of the rod in water. The wooden rods which are generally used, soaked in water, and joined by iron straps, are heavier, and but a little heavier, than water, and they are generally about one-third of the bulk of the water in the pumps.

These two motions complete the period of the operation; and the whole may be repeated by shutting the steam-cock and opening the injection-cock whenever the piston has attained the proper height. We have been very minute in our attention to the different circumstances, that the reader may have a distinct notion of the state of the moving forces in every period of the operation. It is by no means sufficient that we know in general that the injection of cold water makes a void which allows the air to press down the piston, and that the re-admission of the steam allows the piston to rise again. This lumping and slovenly way of viewing it has long prevented even the philosopher from seeing the defects of the construction, and the methods of removing them.

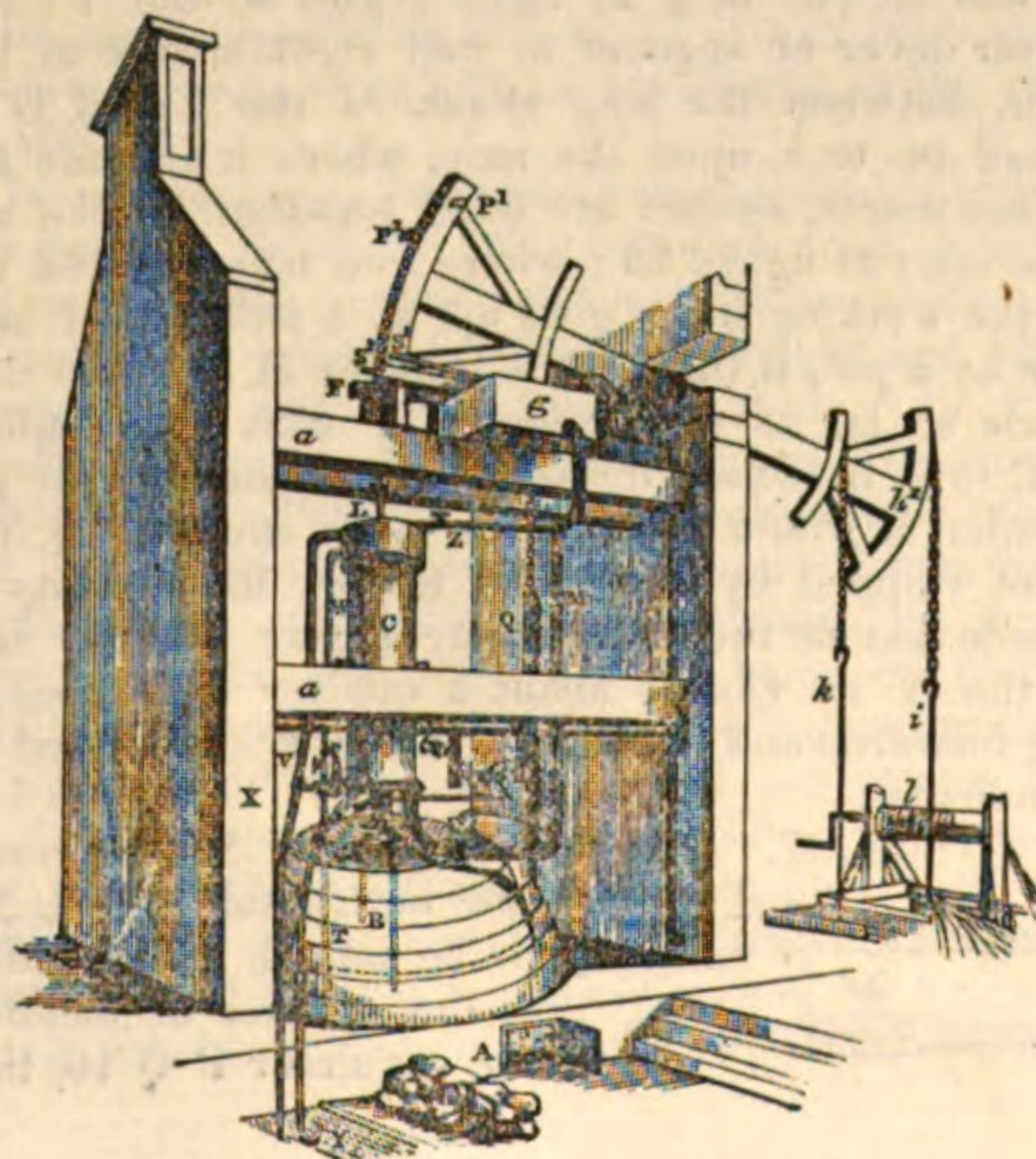
It was in 1718, as already mentioned, that Mr Henry Beighton improved the steam-engine of Newcomen, by a simple and effective arrangement of minor details, which left so little to be desired for the practical use of the engine in pumping water, that for more than half a century it remained in general use, without any change of form or arrangement. The following excellent diagrams and quaint descriptions are from the pen of Desaguliers, who had made himself very well acquainted with the subject as it existed in his time.

Steam-Engine.

The counter-weight is different during the two motions of the pump-rods.

1718. Beighton's valve gear.

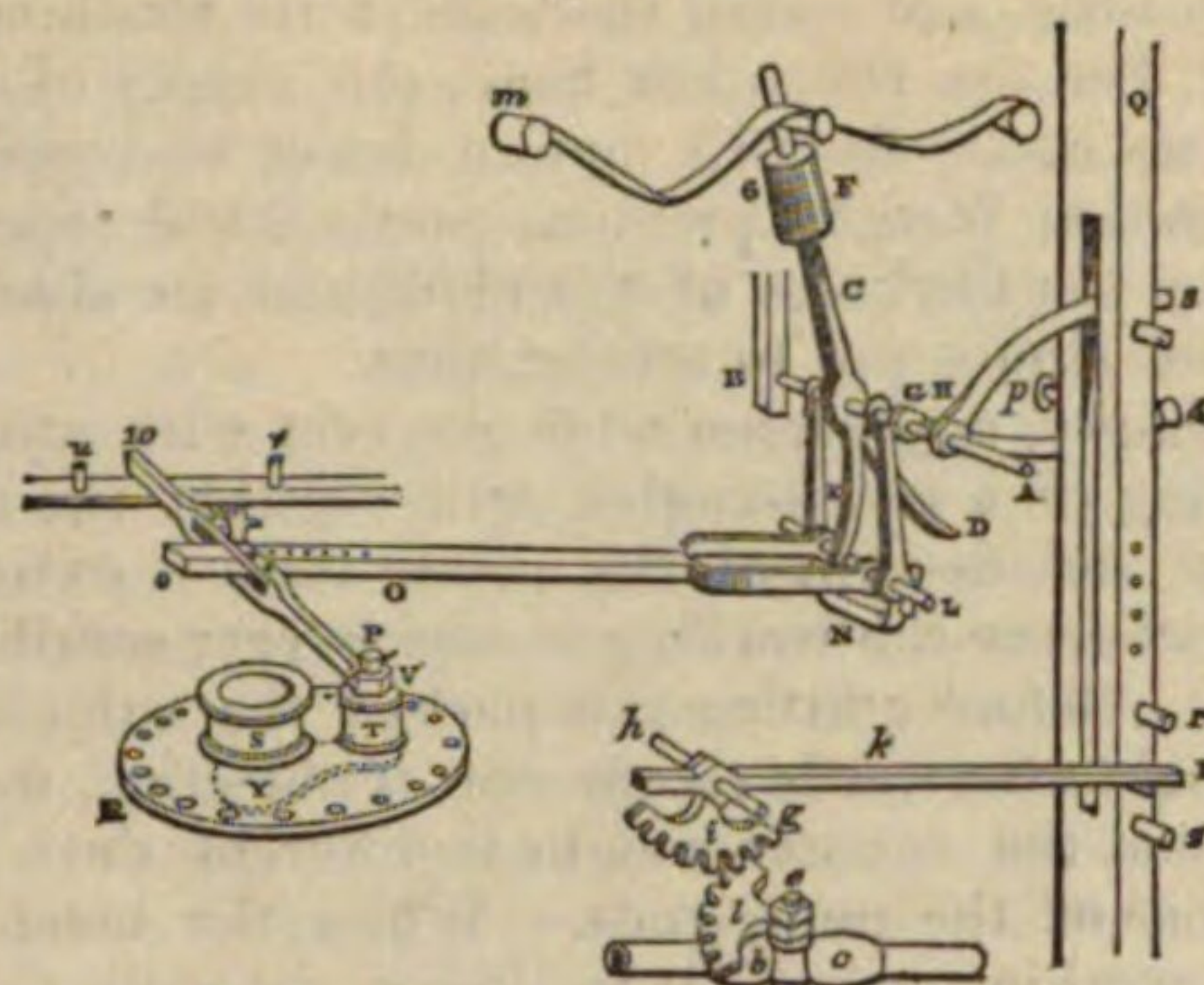
Fig. 24.



Steam-Engine.

Des-gu-liers' de-scription of Beighton's gear.

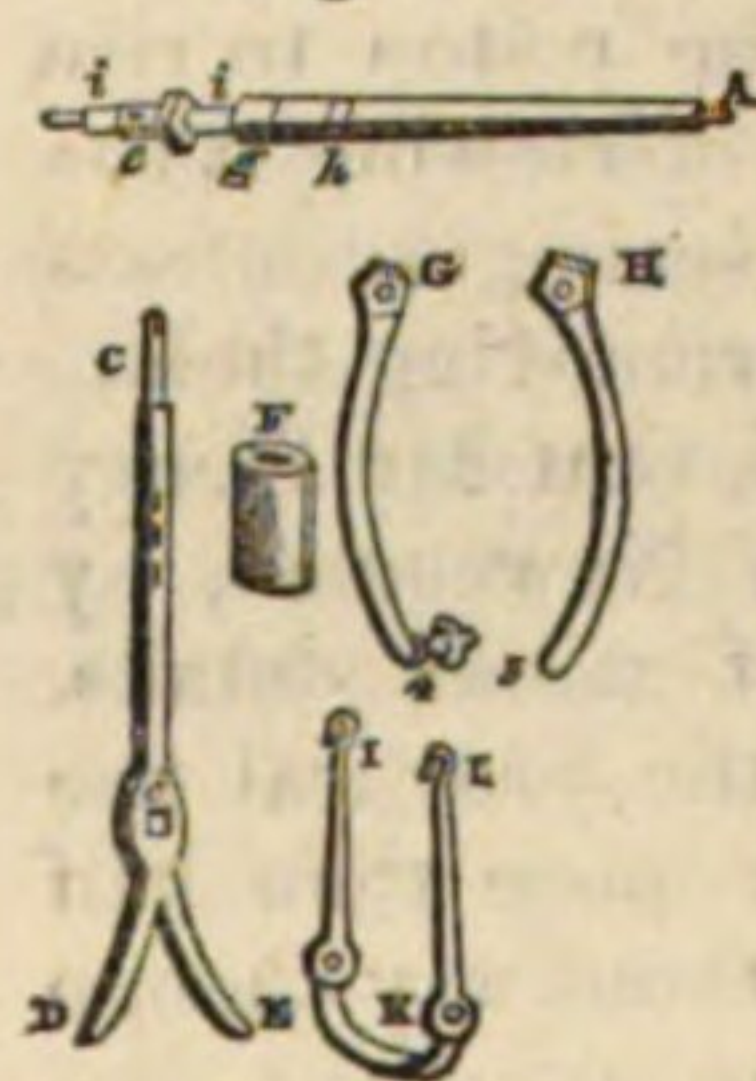
Fig. 25.



"The working perpendicular beam is in figure 24 represented in the whole, with all its contrivances for opening and shutting the regulator and injection-cock, and marked QQ.

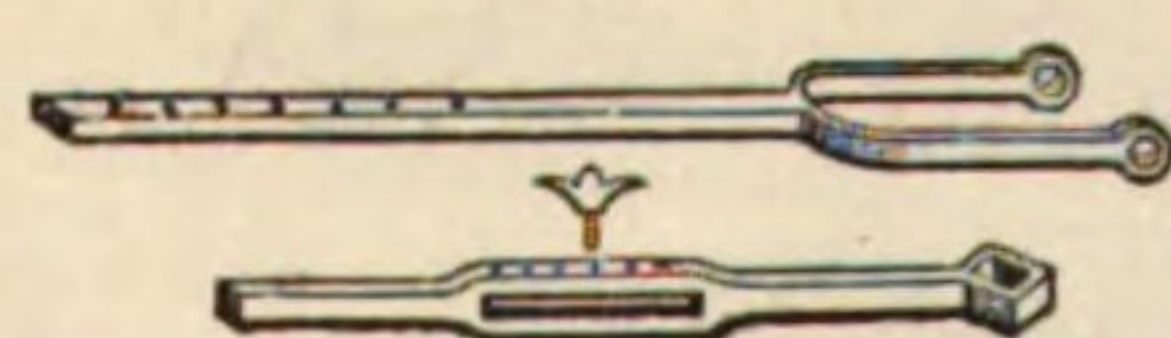
"Between two perpendicular pieces of wood on each side of P, there is a square iron axis, which has upon it four iron pieces subservient to the turning of the regulator, by shooting forward and drawing back the fork fastened to the hand of the regulator; it is marked LNO in fig. 25, and represented separately in fig. 27. There is a slit in the perpendicular working-beam contrived in such manner that its pins work on the fore part, middle, and back part, to raise and depress the levers 5, 4, (fig. 25,) that move the iron axle-tree above-mentioned as far about its centre as is necessary. But the reader will conceive the thing better by a view of the pieces in figs. 26 to 29, and then be enabled fully to understand the same things in fig. 25.

Fig. 26.



"Figure 26 represents the iron axle-tree already mentioned, and marked by the letters A B in figure 25. There is a piece *ce* D E, called the Y, from its representing that letter by its two shanks, only hanging down in an inverted order, with a weight F to be slipped on upon its upper part, where it is made fast, higher or lower, as is convenient, with a key or wedge. This Y being slipped on over the end of the iron axle is made fast by driving in a key after it at *e*: then there is a sort of a stirrup, I K I, with a long pin to be fixed occasionally into the holes on each side of K: this, by its hooks I I, is hung upon the axle at *i i*, then a spanner or handle G 4 is driven on upon the axle from the other end, so as to come and be fast at *g* at right angles to the Y: then a shorter lever or spanner at half right angles to this, (that is, between the long shank of the Y and G 4,) is forced on to *h*, upon the axle, where it is made fast. All these pieces, as they are fixed together on the axle may be seen at figure 25; where you may observe, that when the working beam goes up, by a pulley held in its middle by a pin, it lifts up the spanner H 5, which turns the axle so far as to throw the Y with its weight F from C to 6, in which direction, after passing the perpendicular, it would continue to move towards Q, if it was not stopped by a strap of leather fixed to its top and made fast at the points *m n*, in such manner as to allow the Y to vibrate about a quarter of a circle, in falling forwards and backwards, after it has passed the perpendicular.

Fig. 27.



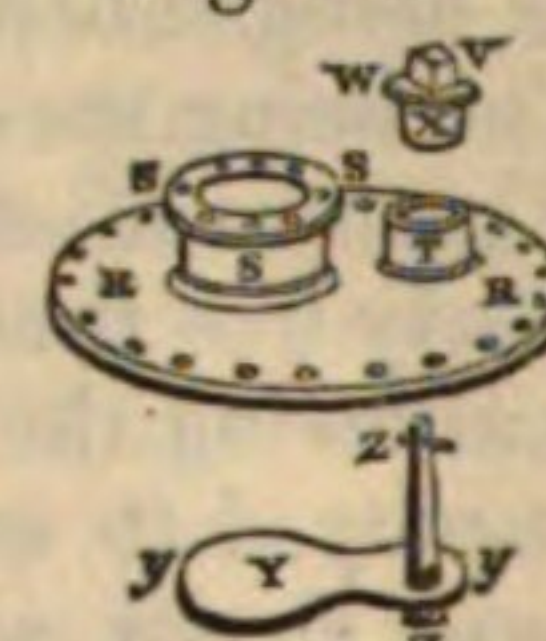
"Figure 27 represents the horizontal fork LNO to be joined, at its end O, to the spanner or handle of the regulator P Q 10, there

being several holes in these pieces, that any part of the end O may be kept in any part of the slit in the spanner, as may be requisite for the better motion of the two pieces. This may be seen in figure 24, where the other end of the fork is fastened to the bottom of the stirrup at K N L, by the long horizontal pin L, so that the fork may continue horizontal, as it is shot forward, and drawn back by the strokes that K and D, the shanks of the Y, make alternately on the fore part or back part of the pin L, in order to push forward, or draw back the spanner P 10, to shut or open the regulator in the manner that shall be further explained. We will only take notice now, that there is an horizontal piece *ul*, so placed, that the end 10 of the spanner may bear upon it, and be supported, as it slides backward and forward.

"Before we proceed, it will not be improper to give a full description of the regulator. See fig. 28.

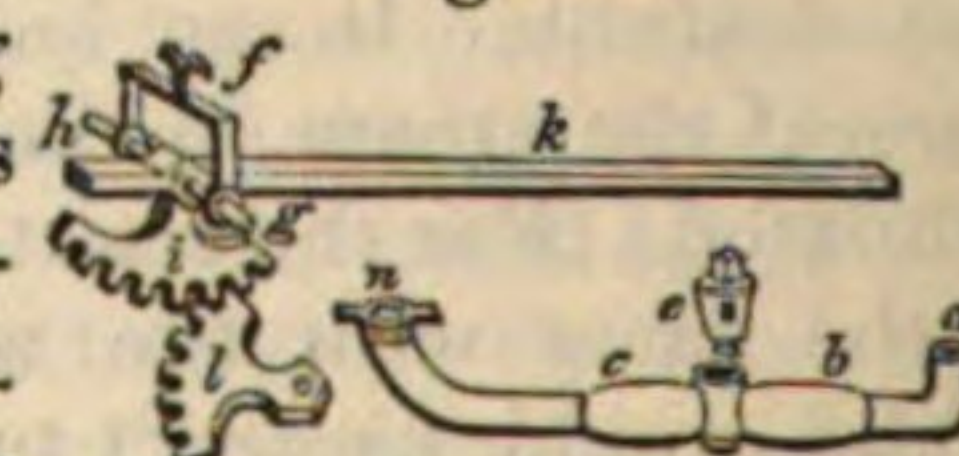
"A cock of four inches water-way, big enough to let the steam out of the boiler into the cylinder, would have so much friction, if made tight, as to require a great force to turn it, especially as it must open and shut 32 times in a minute; therefore the regulator has been contrived instead of it. The brass plate R, which you see here at RR in the middle of the top of the boiler, is cast with the pipe SSS of four inches' bore, and worked smooth at its hole under the plate, that it may be closely stopped by another smooth plate *y* Y *y* applied under it, (where the pressure of the steam will hold it the closer when shut.) There is also, in the plate RR, a short pipe or conic hole T, smallest downwards, to receive the piece V W X, which being ground into it can move round without letting air or steam pass by. There is a square shank ZZ, which is put through this last piece when it is let down into its hole, and pinned tight to it at the upper Z. Then the spanner of the regulator being put on, and made fast at V and W, as may be plainly seen in fig. 25, where the whole regulator is put together. This regulator opens very quick, and ten times easier than a cock of the same bore: and to help the whole, the weight F of the Y, when it has passed the perpendicular, falls with a good force, which makes the shank under it give a smart stroke, either within the fork or without, to drive the fork, and draw the handle of the regulator contrary to the way that the weight is falling: the weight causing the regulator to be shut when it tumbles towards it, and be open when it tumbles from it.

Fig. 28.



"When the regulator is shut, the next thing is to open the injection-cock to make the vacuum, and immediately to shut it when the piston begins to come down, (for the vacuum is made in a second of time.) *n* (fig. 29,) represents the adjutage of the injecting pipe within the cylinder; *a b* part of the pipe coming from the injecting-cistern, *c b* the cock, and *e* the key of the cock, that has a narrow, long, upright hole instead of a round one, that it may be the sooner opened. Upon the top of this key is fastened on a quarter of a wheel with teeth *l*, to be turned by another quarter of a wheel *i* hanging down from the axis *h g*, which is moved by the lever *h k*, commonly called the F. Examine fig. 25, where they are working together, and you may see how the perpendicular beam moves them by its pins.

Fig. 29.



"The present situation of the machine, as now represented by the 24th figure, is as follows. The regulator is open, as appears by its plate TY being removed from under the communication or throat-pipe S, that goes into the cylinder. The piston is now up about the place CW, at top of the cylinder in figure 24; consequently

Steam-Engine.

Desaguliers' description of Beighton's working gear.

the great beam, and the working perpendicular beam are now almost at their utmost height, and the pulley in the slit of the working beam has so far raised the spanner H 5, that the weight or head of the Y is brought so far from under *n*, as to be past the perpendicular over the axle; and being ready to fall over towards *m*, it will with a smart blow of its shank K, strike the pin L, and drawing the fork ON horizontally towards the working beam, will draw the end 10 of the handle of the regulator toward *l*, and thereby shut it, by slipping the plate Y under the pipe S. The engine in figure 25 is in this very condition; but in figure 24 the blow is already struck, and the communication cut off; as may be known by observing that the weight at the head of the Y is got as far as the strap will let it go.

"The moment after the regulator is shut, the beam not immediately losing its motion upwards, the pin *s* on its outside lifts up the end I of the F, *h k i*, and opens the injection-cock; and the jet immediately making a vacuum, the beam begins to descend, and the pin *r* (which you may put higher or lower) depressing the F, shuts the injection-cock: then the beam continuing to descend, the pulley *p*, pressing on the handle G 4, throws back the Y, whose shank D throws forward the fork, and opens the regulator to let in fresh steam, in the manner already described; which steam is shut off, by shutting the regulator till the cock for injection of cold water is again opened."

Smeaton's improvements, 1770.

Newcomen, Potter, and Beighton, had thus rendered the atmospheric steam-engine an independent self-acting mechanical power of so great perfection in its principle of action, and its minor details, as to be very generally introduced as a substitute for the power of animals in draining mines and collieries, and to confer very great advantages in those important and primary sources of national industry and wealth. The saving of money resulting from this change was so great as to be continually opening up new avenues of mining enterprise; and, by the rapid progress of that enterprise, the capabilities of the engine were soon put to the severest trial. The cylinders, which had been originally of twelve and sixteen inches diameter, were increased to twenty, thirty, and forty inches, and at last even fifty and sixty inches in diameter. Along with this dimension, the other parts required to be increased in a still higher proportion; and at last the structures became so gigantic as to demand an amount of science and practical skill which in that period of engineering science was rarely to be found. The man suited to the emergency at last arose in the father of civil engineering, the justly celebrated Smeaton, who brought to bear on this subject endowments and accomplishments seldom united; fertile ingenuity, accurate philosophic conceptions, and sound practical sagacity. He conferred upon the atmospheric steam-engine all the extent and variety of application of which it was capable, and all the perfection of proportion and execution which the state of the mechanical arts would permit.

The manner in which Smeaton proceeded to the improvement of the atmospheric engine was one which is worthy of all praise and imitation. Unlike too many of the engineering experiments of the present day, as well as of past times, his were made at his own expense, not at the expense of his employers, and on a scale sufficiently large to ensure sound results, without being on that scale which should entail unwarrantable expense. Having encountered some anomalous results in the earlier parts of his experience with atmospheric engines, he resolved, as he says, "if possible to make himself master of the subject, and immediately began to build a small fire-engine, which could easily be converted into different shapes for experiments." This experimental engine was set to work at Austhorpe in 1769. With it he made a

very great number of valuable experiments, so as to ascertain the length and velocity of stroke and return, the quantity and manner of injection, the proportion of load, the dimensions of cylinder, and the materials of construction, which were required to produce the maximum of useful effect from a given amount of fuel. Mr Farey has given us the dimensions of this model, and the results of the experiments of Smeaton as they are here set down. The cylinder was 9.9 inches in diameter, and had a working-stroke of 3 feet. The piston made $17\frac{1}{2}$ strokes per minute passing over 105 feet per minute in going and returning, or over 52.5 effective feet per minute; its load per square inch was 7.89 lbs., its total load 607 lbs. The quantity of coals consumed was 55 lbs. per hour. The work done was equivalent to 31,867 lbs. raised 1 foot high per minute = 0.966 horse power. The work of one bushel or 84 lbs. of coal was equal to 2,919,017 lbs. raised 1 foot high. The weight of water evaporated by 1 lb. of coal was 6.14 lbs., and the quantity of cold water injected was 10.66 the evaporated water.

When the engine made its stroke the mercury was raised to 23.2 inches.

Mr Smeaton found that this engine produced its maximum effect both as regards quantity and economy when carrying a load of 7.81 lbs. on the inch. When the load was reduced to 6.6 lbs. the power of the engine was lessened in the proportion of 100. to 94. When the load was reduced to 5.5 lbs. the power of the engine was still further lessened in the proportion of 94 to 82. In these two cases the work produced by 1 lb. of coals was reduced in the proportion of 100 to 94, and 94 to 80.

When, on the other hand, the load was increased from 7.8 lbs. to 8.8 lbs. per inch, the work done was only increased from 100 to 107. When the load was still further increased to 9.1 lbs. the work was diminished from 100 to 96. But in both these the economy of fuel was diminished in a higher proportion, the work produced by each lb. of coals being reduced in the proportions 100 to 97, and 97 to 93.

Mr Smeaton also found, from the same engine, the best kinds and modes of burning the fuel. Round coals were found superior to small coal in the proportion of 100 to 80 nearly. Coke produced $\frac{5}{8}$ of the effect of an equal weight of the same coal from which the coke was made, and 66 lbs. of coke were obtained from 100 lbs. of coal. Ash-wood used as fuel was found inferior to common Yorkshire coals in the proportion of 42 to 100. The performance of the kind of Newcastle coals called Team Top, was found superior to the common Yorkshire or Halton coal. in the ratio of 120 to 100. Cannel coal, from Wakefield in Yorkshire, was superior to Halton in the ratio 133 to 100. Middleton-wood coals, and Welsh coals, were superior to Halton, as 110 to 100; and Berwick-moor coals were inferior to Halton, in the ratio 86 to 100.

In consequence of this admirable method of procedure, Mr Smeaton improved the proportions and structure of the atmospheric engine, and very soon produced machines which excelled in their dimensions and efficiency every thing which had preceded them. In 1772 he erected an engine at Long Benton colliery, near Newcastle, which he ever afterwards considered as his standard. The following are its principal dimensions and performance: Diameter of the cylinder, 52 inches—7 feet stroke, 12 strokes per minute, being 84 feet useful motion per minute, and 168 feet total motion per minute. Load of water = 7.1 tons. Load per square inch = $7\frac{1}{2}$ lbs. Consumption of coals, 17.63 lbs. per horse power per hour. Work of one bushel or 84 lbs. of coals = 9.45 millions of lbs. one foot high. The total power of engine was about $40\frac{1}{2}$ horse-power, and for every horse-power the boiler had 52 cubic feet of total space, 27.75

Steam-Engine.

Smeaton's experimental engine.

Steam-Engine.

cubic feet of steam room, and 6.25 square feet of horizontal surface of water. The furnace had, for every horse power, 3.5 square feet of fire surface, 7.83 square feet of flue surface, and .867 square foot of fire grate. The total steam produced per minute was about 62.95 feet per horse power; of this 30.58 feet were used in moving the piston, 8.92 feet wasted to fill the extra space in the cylinder, and 23.45 condensed on the surface of the cylinder.

Mr Farey has given an excellent description and investigation of this engine, with two plates taken with his wonted fidelity and beauty, from the original drawings.

Smeaton's Portable Engine.

Mr Smeaton also constructed a portable fire-engine, for the purpose of being used to draw water from temporary excavations, shafts, quarries, &c., so framed as to require no erection of a building, and to be easily removed from place to place. The fire is wholly within the boiler. The framing of the engine is constructed of timber, trussed and arranged in such a manner as to contain within it every kind of strain whatever which the force of the machine and the resistance may produce. The details of this engine are given in his reports, from which we extract the following drawings and descriptions:

Fig. 30.

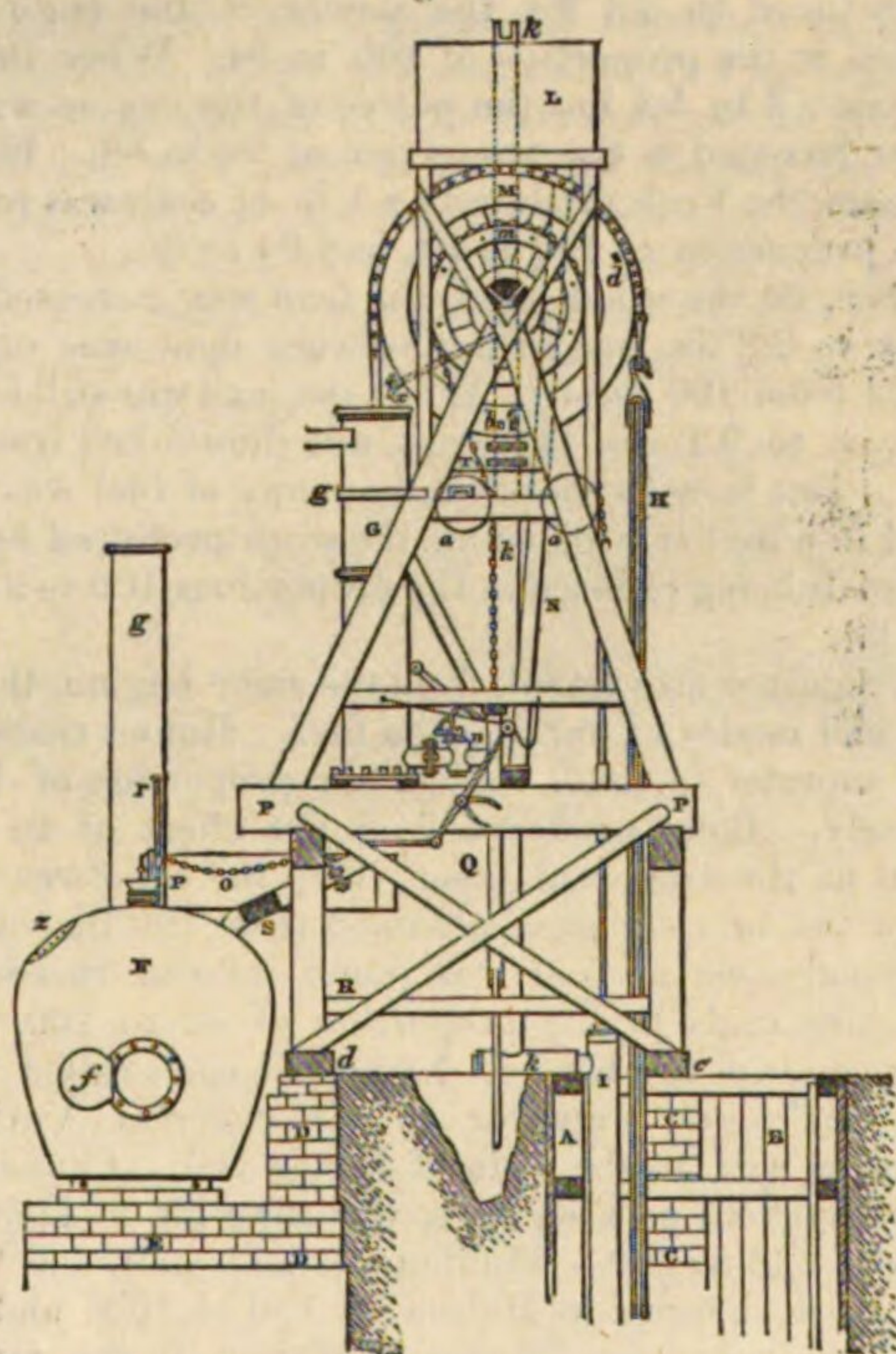


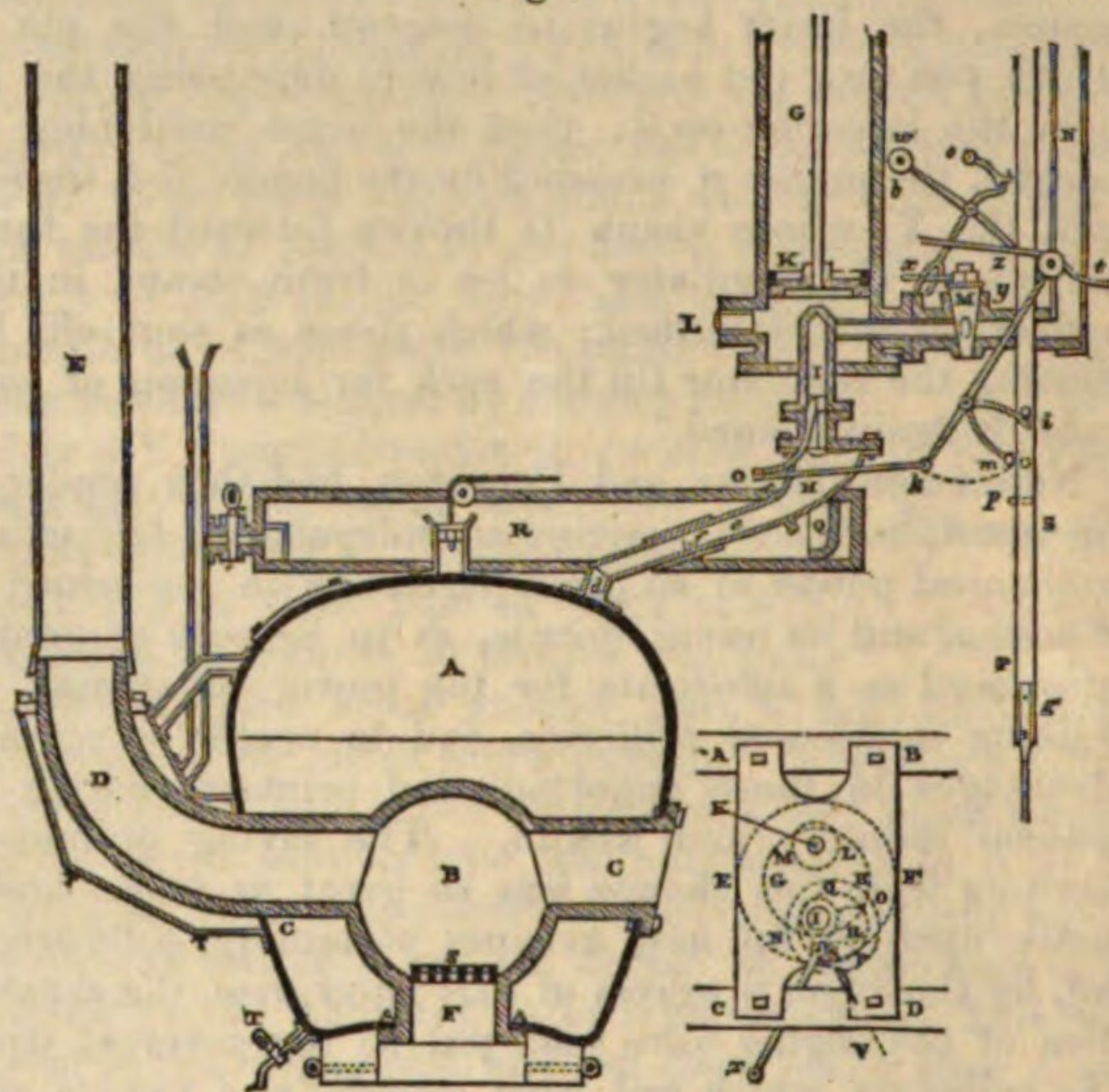
Fig. 30 contains a side view of the engine and boiler. AB is the pit or shaft. CC is the upright of the foundation walls on each side of the pit, for supporting the groundsill *c* across the pit, upon which one side of the engine-frame is raised. DD is the foundation wall for supporting the groundsill *d*, upon which the other side is raised; E the foundation wall for supporting the boiler, and forming the ash-hole. F is the boiler, *f* the fire-door, *g* the chimney, S the steam-pipe, *p* the puppet-clack, *r* the feeding-pipe funnel, *z* the man-hole, G the cylinder, H the main pump spear, I the jackhead-pump, by the continuation whereof, *kkk*, the water, is conveyed into L, the injection-cistern. M is a wheel serving instead of the great beam, *m* a rim of a smaller diameter, attached to the former, for working the jackhead-pump I, and plugframe Q. *aa* are pulleys to bring their chains into a convenient place

for working. The wheel is stopped at the end of its intended stroke, which is to be $6\frac{1}{2}$ feet stop and stop, by means of the two iron fids *bb*, which, reaching out on each side of the great rim, stop against two strong iron pins *ee*, which are fixed into a cross beam S, framed into the piece T, and the whole firmly bolted together, as shown in the design. N is the injection-pipe, *n* the injection-cock, and *x* the piston water-cock. O is the hot well. R is a stage for the person to stand upon who hands the engine. PP are the two main beams or sleepers, upon which the cylinder is seated upon its bottom and bolted down. The whole is kept from springing or flying off by an iron strap.

Steam-Engine.
Smeaton's Portable Engine.

The waste water pipes are omitted to prevent confusion. Fig. 31 shows a section of the boiler, cylinder, and pipes, with the working-gear, to a larger scale, the whole being divested of the framing in order to render every thing more distinct.

Fig. 31.



The boiler is supposed to be turned one quarter round from its true position, in order that the most material parts may be brought into one view. It is also to be noted, that every vessel or pipe is supposed to be cut right through the middle, in order to show the contents, and that the section is not confined to any particular plane; but, for the more perfect explaining of the principal figure, it will be best to begin with the little plan at the right-hand corner of the figure. ABCD is a plan of the cylinder bottom, bolted down upon the two main beams AB and CD; the dotted circle EF shows the extremity of the bottom flanch of the cylinder, and the circle GH, the diameter of the cylinder within; the hole I answers the steam-pipe and regulator, and the hole K the eduction or sinking-pipe, and the circle LM its flanch; the circle NO shows the size and position of the regulator-plate, and the dotted circle PQ the size of the receiver in which the sliding-valve of the regulator R works, and in this position is open; ST is the lever by which it is worked, and when that is brought forward into the position SV, then the valve covers the aperture of the regulator. In the principal figure A is the boiler, and B the fire-place which is of cast iron, and of a spherical form, and placed in the interior of the boiler. The coals are introduced by the large pipe C, and the smoke is conducted by the curved pipe D into the funnel or chimney E. The ashes fall through the grate S and the wide pipe F, into the ash-holes below. The other appendages of the boiler, are a cock for emptying it, marked T, two

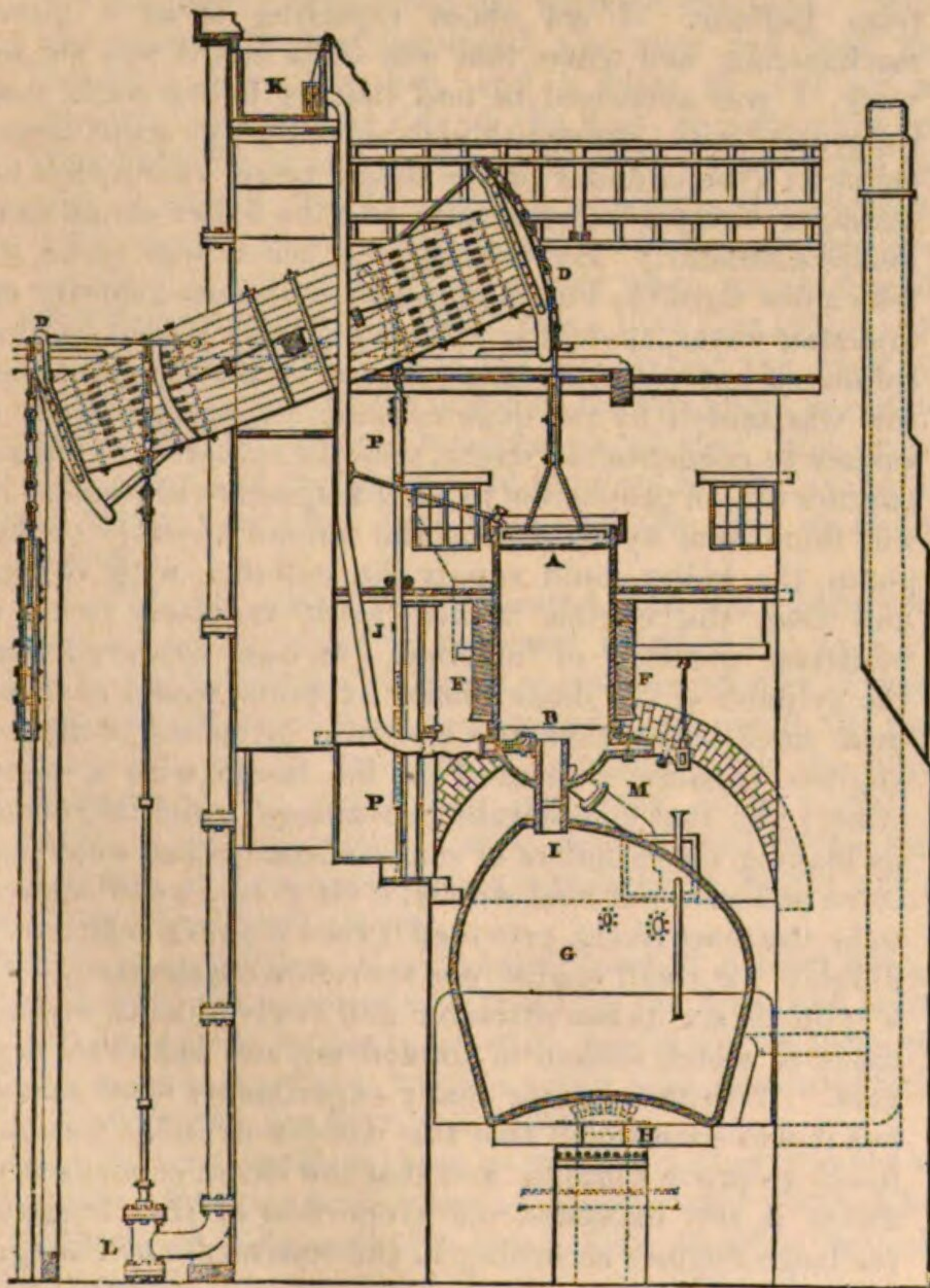
Steam-Engine.

gauge-cocks for ascertaining the height of the water, the puppet-clack or safety-valve, loaded with a sufficient weight, and having a string attached to it, so that the attendant on the engine can raise it when necessary to allow the steam to escape. The boiler has also a man-hole, which is better seen at Z in fig. 30. The curved smoke-pipe D is surrounded by a copper casing, into which the water for feeding the boiler flows from the hot well, so as to be highly heated before being admitted into the boiler. The other parts of the engine shown in the figure are, G the cylinder, into which the steam from the boiler flows through the pipes *d e H I*, which are jointed at *f* for the readier taking asunder, K the piston, G the piston-rod, H the receiver for the steam, containing the regulator-valve, I the steam-pipe, L the snifting-clack, M the injection-cock, N the injection-pipe, P *p y* the plug-frame, *e m* arms of the tumbler on which the plugs act, *k o* a rod connecting the end of the tumbler with the handle of the regulator, *w b x z* the faller or F lever, with its detent or catch at *o*.

Smeaton's Great Chase-water Engine.

But the most magnificent of Smeaton's works in this department of his profession is his great Chasewater engine, of which the details are given in his Reports. This engine was of 150 horses' power, turning out 880 hogs-heads of water per hour, by the heat of $16\frac{1}{2}$ bushels of coal. We have given a cut of this engine, Fig. 32; and we recommend the engineer to consult the original in Smeaton's Reports, as it is full of ingenious contrivance and judicious arrangement. The cylinder AB is 72 inches in diameter, the stroke 10 feet 6 inches. The great beam of the engine, DD, consists of twenty large balks of timber, the four nearest the centre being each a foot square, and the whole firmly joggled together with heart of oak, and bolted with iron, forming a very elegant but ponderous beam. The cylinder beams FF, upon which the cylinder rests, and which are kept in their place by being

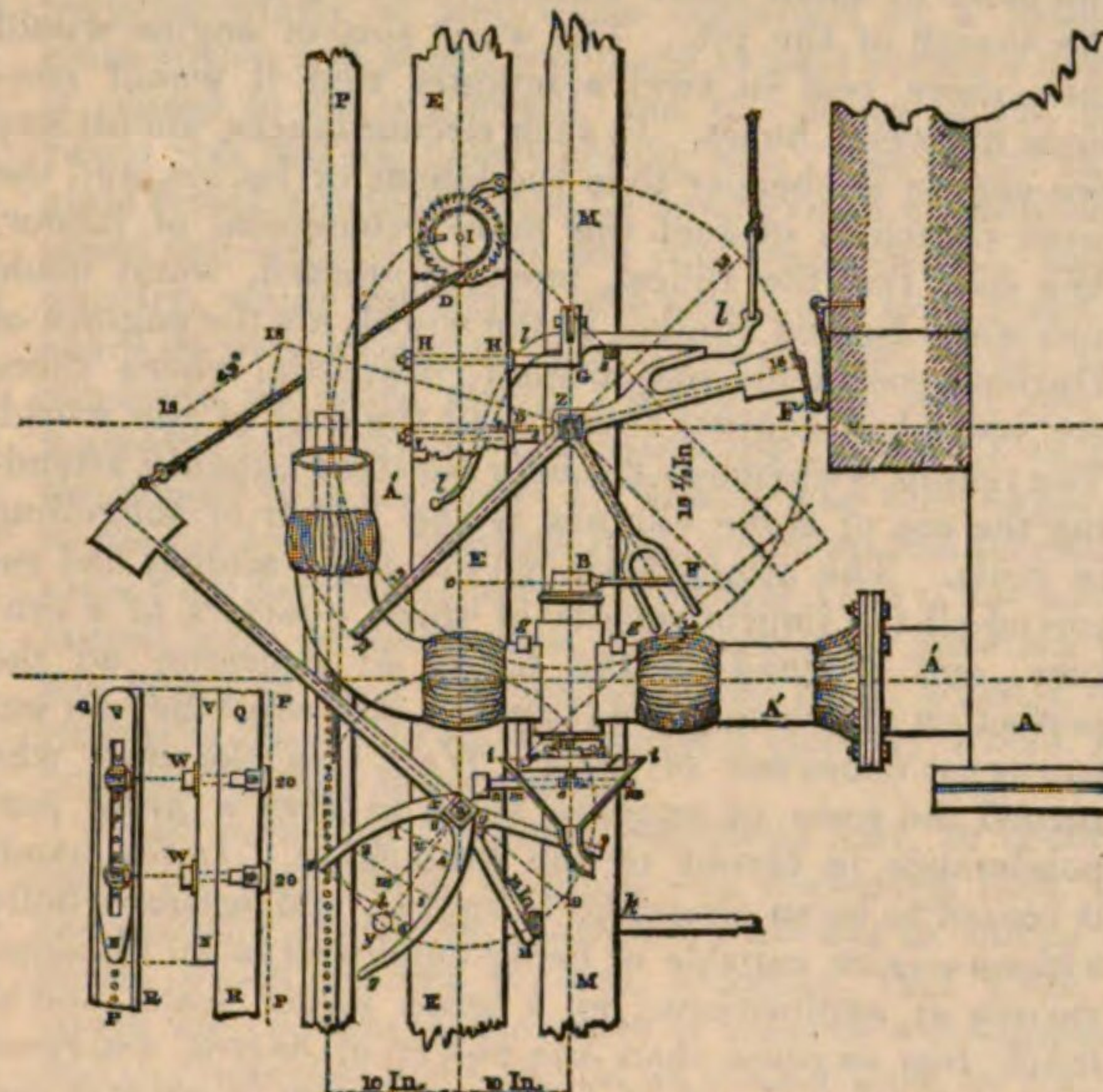
Fig 32.



entered into the side walls of the house, are joggled and framed together in a similar manner to the great lever. G is the boiler, H the furnace, I B the steam-pipe, J the injection-pipe, K the cistern for the injection water, fed by a pump L, which is wrought by the great lever of the engine, M the waste-pipe for the condensed steam, N the spear or pump-rod of the great draining-pump wrought by the engine, P P the plug-tree suspended from the main beam carrying plugs, which in its upward and downward progress act on the levers which open and shut the regulator and injection-cocks. The date of this engine is 1775. The working gear of the engine is very simple and good. It is represented on a larger scale in the accompanying cut, fig. 33.

Steam-Engine.

Fig. 33.



A is the lower corner of the cylinder, A' A' A' the injection-pipe, B the injection-cock, B F its handle or spanner passing between the forks of the bent lever E Z F F', called the F lever, by which the cock is opened and shut. The tail Z 12 of this F lever is, by the downward motion of the plug-tree P, forced from the position shown by the dotted line Z 18, into the position in which it is seen in the drawing, and it is there retained by the catch *l l l*. While the lever is in this position the injection-cock is shut, the steam from the boiler is flowing into the cylinder, and the piston is rising. When the piston has nearly reached the top of its course, an apparatus attached to the plug-frame P, draws up the catch *l l l*, and releases the F lever, which is forced into the position 18 Z, by the bob or weight 16, carried by its end F', and the consequent movement of its fork F opens the injection-cock; T x 11, 9, is the Y lever or tumbler, which acts upon the stirrup-rod *k* attached to the spanner of the regulator, as in Beighton's gear, figs. 25, 27. The range of the tumbler's motion on each side of the perpendicular is regulated by its check-cord T I, which is passed round a roller I, furnished with a paul and ratchet, so that its length may be adjusted. The tumbler is moved by pins in the plug-frame P, acting upon its bent arms *x 3*, *x 7*.

In the left-hand corner at the bottom of the figure is seen a representation of a slider, which may be fixed upon the plug-tree instead of the pins, to work the lever. There is both a side and a front view of the slider. Q R shows a part of the plug-tree, N V the slider, and W 20 W 20 two screws for retaining the slider in its place. By this

Steam-Engine.

Inventions of James Watt.

Watt's History of his own Improvements.

1759.

means the working-stroke may be adjusted much more surely than by the pins or plugs.

The working of the injection-cock by the forked end of the F lever was found to be defective, and Mr Smeaton, in the engines which he afterwards constructed, fixed a toothed sector on the end of the lever, which was made to act upon a toothed wheel, carried by the axis of the injection-cock, somewhat in the manner of the parts of Beighton's gear represented in figs. 25, 29.

III. *The Era of Watt.*—Before the time of James Watt, the steam or atmospheric engine was a more costly power than horses, except where fuel was extremely cheap. At the mouth of a coal-pit almost any sort of steam-engine or fire-engine is better than horses, because it consumes the produce, and often the refuse of the pit, and is valuable for the purpose of volatilising the mass of small coals which would otherwise lumber the mouth of the pit. The worst sort of engine would raise more coal in twelve minutes than it would consume in twelve hours. In such circumstances, almost any fire-engine is cheaper than the labour of horses, and the more voracious of fuel the more economical of labour. We find that the rudest, most antiquated, worst made and worst tended engines in the world, are the engines of Durham coal-fields and around Newcastle, where there are more bad engines than in all the rest of the world. The reason is obvious; the only constant expense attending the use of these engines is the labour of shovelling in coals. The atmospheric engine, even after it had received all the improvements of three quarters of a century, and attained in the hands of Smeaton all the perfection of which it was capable, still continued an extravagant consumer of coals. Watt was the man who turned the scale of expense so as to give a great preponderance in favour of the fire-engine. In his hands it ceased to be an *atmospheric engine*, and became wholly a *steam-engine*, capable of being employed in an immense variety of applications, on a much larger scale, and at much less expense than the power of horses, wherever the prices of fuel and of fodder were not in greater disparity than in this country.

We have seen that hitherto the fire-engine, even in Smeaton's hands, was an engine that wasted a large quantity of fuel and of steam in doing what was useless, namely, heating the cylinder, which was cooled alternately in each stroke by the cold water injected into it. In Long Benton colliery engine, out of sixty-three cubic feet of steam thirty-two feet were thus wasted, and the remaining thirty-one feet alone performed useful work. There remained, therefore, one-half of the power of the steam and expense of the fuel to be saved by future improvements, provided the useless heating and cooling of the cylinder could be superseded. The vacuum formed below the cylinder was also far from being perfect. Watt found the atmospheric fire-engine in the hands of Smeaton, produced from it the pure steam-engine, and left it to us in its present state of high improvement. This portion of the history of the steam-engine has been contributed as a commentary upon the original article of this Encyclopædia by the person of all others best qualified to do it justice, Watt himself. For the purpose of further illustration, we have added some figures, as well as some remarks.

“My attention was first directed in the year 1759 to the subject of steam-engines by the late Dr. Robison, himself then a student in the University of Glasgow, and nearly of my own age. He at that time threw out an idea of applying the power of the steam-engine to the moving of wheel carriages, and to other purposes, but the scheme was not matured, and was soon abandoned on his going abroad.

“About the year 1761 or 1762, I tried some experiments on the force of steam, in a Papin's digester, and formed a species of steam-engine by fixing upon it a syringe one-third of an inch in diameter, with a solid piston, and furnished also with a cock to admit the steam from the digester, or shut it off at pleasure, as well as to open a communication from the inside of the syringe to the open air, by which the steam contained in the syringe might escape. When the communication between the digester and syringe was opened, the steam entered the syringe, and by its action upon the piston raised a considerable weight (fifteen lbs.) with which it was loaded. When this was raised as high as was thought proper, the communication with the digester was shut, and that with the atmosphere opened; the steam then made its escape, and the weight descended. The operations were repeated, and though in this experiment the cock was turned by hand, it was easy to see how it could be done by the machine itself, and to make it work with perfect regularity. But I soon relinquished the idea of constructing an engine upon this principle, from being sensible it would be liable to some of the objections against Savary's engine, viz. the danger of bursting the boiler, and the difficulty of making the joints tight, and also that a great part of the power of the steam would be lost, because no vacuum was formed to assist the descent of the piston.

“The attention necessary to the avocations of business prevented me from then prosecuting the subject further; but in the winter of 1763-4, having occasion to repair a model of Newcomen's engine belonging to the Natural Philosophy Class of the University of Glasgow, my mind was again directed to it. At that period, my knowledge was derived principally from Desaguliers, and partly from Belidor. I set about repairing it as a mere mechanic, and when that was done and it was set to work, I was surprised to find that its boiler could not supply it with steam, though apparently quite large enough; (the cylinder of the model being two inches in diameter, and six inches stroke, and the boiler about nine inches diameter.) By blowing the fire it was made to take a few strokes; but required an enormous quantity of injection water, though it was very lightly loaded by the column of water in the pump. It soon occurred to me, that this was caused by the little cylinder exposing a greater surface to condense the steam, than the cylinders of larger engines did, in proportion to their respective contents. It was found that by shortening the column of water in the pump, the boiler could supply the cylinder with steam, and that the engine would work regularly with a moderate quantity of injection. It now appeared that the cylinder of the model, being of brass, would conduct heat much better than the cast-iron cylinders of larger engines, (generally covered on the inside with a stony crust,) and that considerable advantage could be gained by making the cylinders of some substance that would receive and give out heat slowly. Of these, wood seemed to be the most likely, provided it should prove sufficiently durable. A small engine was therefore constructed, with a cylinder six inches diameter and twelve inches stroke, made of wood, soaked in linseed oil, and baked to dryness. With this engine many experiments were made; but it was soon found that the wooden cylinder was not likely to prove durable, and that the steam condensed in filling it still exceeded the proportion of that required for large engines according to the statements of Desagu-

Fig. 34.



Steam-Engine.

Watt's History of his own Improvements. 1761

Steam-Engine.

Watt's History of his own Improvements.

1763.

liers. It was also found, that all attempts to produce a better exhaustion by throwing in more injection, caused a disproportionate waste of steam. On reflection, the cause of this seemed to be the boiling of water in vacuo at low heats, a discovery lately made by Dr Cullen and some other philosophers, (below 100, as I was then informed,) and consequently, at greater heats, the water in the cylinder would produce a steam which would, in part, resist the pressure of the atmosphere.

"By experiments which I then tried upon the heats at which water boils under several pressures greater than that of the atmosphere, it appeared that when the heats proceeded in an arithmetical, the elasticities proceeded in some geometrical ratio; and by laying down a curve from my data, I ascertained the particular one near enough for my purpose. It also appeared that any approach to a vacuum could only be obtained by throwing in large quantities of injection, which would cool the cylinder so much as to require quantities of steam to heat it again, out of proportion to the power gained by the more perfect vacuum; and that the old engineers had acted wisely in contenting themselves with loading the engine with only six or seven pounds on each square inch of the area of the piston. It being evident that there was a great error in Dr Desaguliers' calculations of Mr Beighton's experiments on the bulk of steam, a Florence flask, capable of containing about a pound of water, had about one ounce of distilled water put into it; a glass tube was fitted into its mouth, and the joining made tight by lapping that part of the tube with packthread covered with glaziers' putty. When the flask was set upright, the tube reached down near to the surface of the water, and in that position the whole was placed in a tin reflecting oven before a fire, until the water was wholly evaporated, which happened in about an hour, and might have been done sooner, had I not wished the heat not much to exceed that of boiling water. As the air in the flask was heavier than the steam, the latter ascended to the top, and expelled the air through the tube. When the water was all evaporated, the oven and flask were removed from the fire, and a blast of cold air was directed against one side of the flask, to collect the condensed steam in one place. When all was cold, the tube was removed, the flask and its contents were weighed with care; and the flask being made hot, it was dried by blowing into it by bellows, and when weighed again, was found to have lost rather more than four grains, estimated at four and a third grains. When the flask was filled with water, it was found to contain about seventeen and one-eighth ounces avoirdupois of that fluid, which gave about one thousand eight hundred for the expansion of water converted into steam of the heat of boiling water.

"This experiment was repeated with nearly the same result; and in order to ascertain whether the flask had been wholly filled with steam, a similar quantity of water was, for the third time, evaporated; and, while the flask was still cold, it was placed inverted, with its mouth (contracted by the tube) immersed in a vessel of water, which it sucked in as it cooled, until in the temperature of the atmosphere it was filled to within half an ounce measure of water.

"In repetitions of this experiment at a later date, I simplified the apparatus by omitting the tube, and laying the flask upon its side in the oven, partly closing its mouth by a cork, having a notch on one side, and otherwise proceeding as has been mentioned.

"I do not consider these experiments as extremely accurate; the only scale-beam of a proper size which I had then at my command not being very sensible, and the

VOL. XX.

bulk of the steam being liable to be influenced by the heat to which it was exposed, which, in the way described, is not easily regulated or ascertained; but, from my experience in actual practice, I esteem the expansion to be rather more than I have computed.

"A boiler was constructed, which showed by inspection the quantity of water evaporated in any given time, and thereby ascertained the quantity of steam used in every stroke by the engine, which I found to be several times the full of the cylinder. Astonished at the quantity of water required for the injection, and the great heat it had acquired from the small quantity of water in the form of steam which had been used in filling the cylinder, and thinking I had made some mistake, the following experiment was tried:—A glass tube was bent at right angles, one end was inserted horizontally into the spout of a tea-kettle, and the other part was immersed perpendicularly in well water contained in a cylindric glass vessel, and steam was made to pass through it until it ceased to be condensed, and the water in the glass vessel was become nearly boiling hot. The water in the glass vessel was then found to have gained an addition of about one-sixth part from the condensed steam. Consequently, water converted into steam can heat about six times its own weight of well-water to 212°, or till it can condense no more steam. Being struck with this remarkable fact, and not understanding the reason of it, I mentioned it to my friend Dr Black, who then explained to me his doctrine of latent heat, which he had taught for some time before this period, (summer 1764;) but having myself been occupied with the pursuits of business, if I had heard of it, I had not attended to it, when I thus stumbled upon one of the material facts by which that beautiful theory is supported.

"On reflecting further, I perceived that, in order to make the best use of steam, it was necessary, first, that the cylinder should be maintained always as hot as the steam which entered it; and, secondly, that when the steam was condensed, the water of which it was composed, and the injection itself, should be cooled down to 100°, or lower, where that was possible. The means of accomplishing these points did not immediately present themselves; but *early in 1765 it occurred to me, that if a communication were opened between a cylinder containing steam, and another vessel which was exhausted of air and other fluids, the steam, as an elastic fluid, would immediately rush into the empty vessel, and continue so to do until it had established an equilibrium; and if that vessel were kept very cool by an injection, or otherwise, more steam would continue to enter, until the whole was condensed. But both the vessels being exhausted, or nearly so, how was the injection-water, the air which would enter with it, and the condensed steam, to be got out? This I proposed, in my own mind, to perform in two ways. One was by adapting to the second vessel a pipe reaching downwards more than thirty-four feet, by which the water would descend, (a column of that length overbalancing the atmosphere,) and by extracting the air by means of a pump.*

"The second method was *by employing a pump, or pumps, to extract both the air and the water, which would be applicable in all places, and essential in those cases where there was no well or pit.*

"This latter method was the one I then preferred, and is the only one I afterwards continued to use.

"In Newcomen's engine, the piston is kept tight by water, which could not be applicable in this new method, as, if any of it entered into a partially exhausted and hot cylinder, it would boil and prevent the production of a vacuum, and would also cool the cylinder by its evapora-

4 L

Steam-Engine.

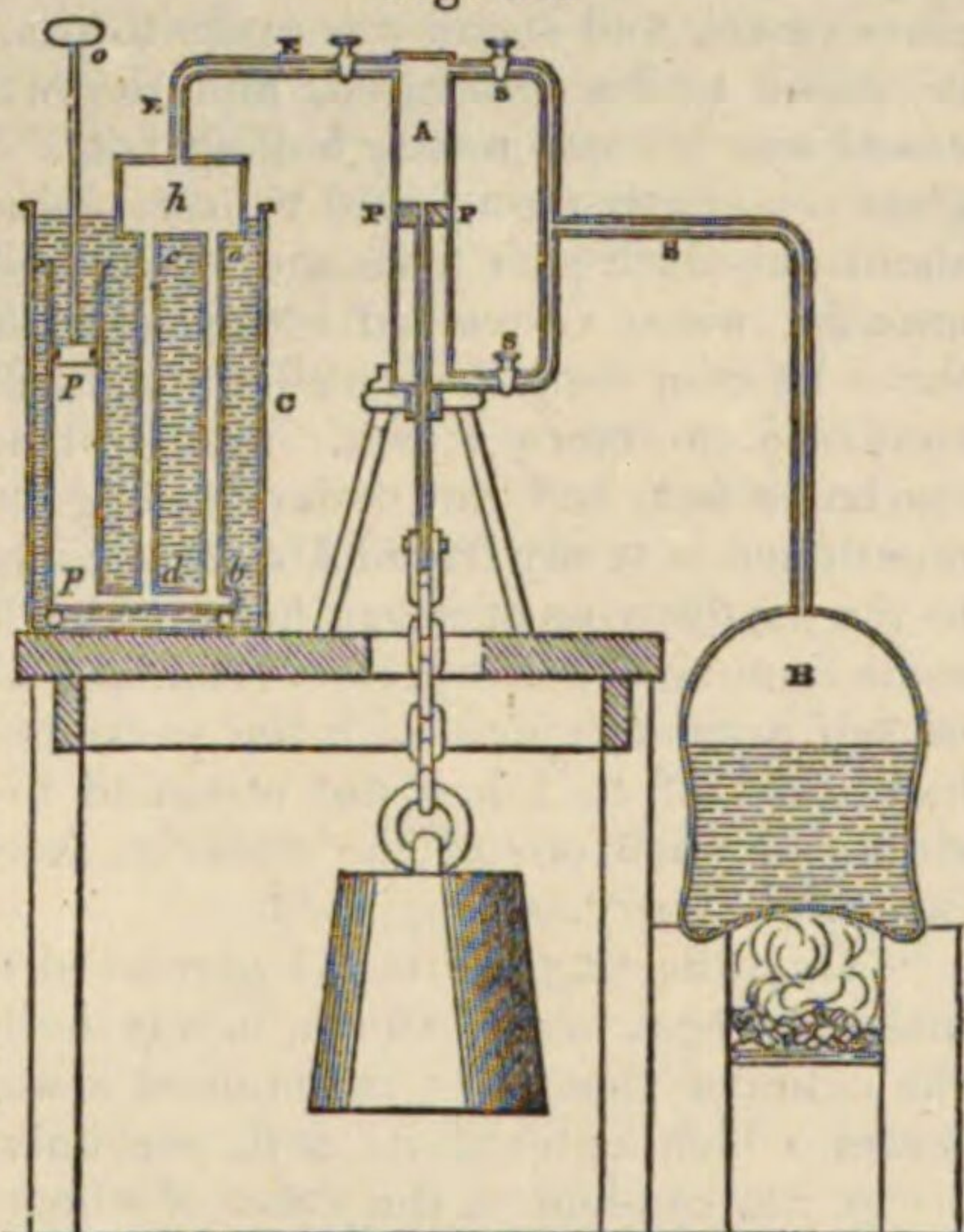
Watt's History of his own Improvements.

Steam-Engine.

Watt's History of his own Improvements.

tion during the descent of the piston. I proposed to remedy this defect by *employing wax, tallow, or other grease, to lubricate and keep the piston tight.* It next occurred to me that the mouth of the cylinder being open, the air which entered to act on the piston would cool the cylinder, and condense some steam on again filling it; I therefore proposed to *put an air-tight cover upon the cylinder, with a hole and stuffing-box for the piston-rod to slide through, and to admit steam above the piston to act upon it instead of the atmosphere.* There still remained another source of the destruction of steam, the cooling of the cylinder by the external air, which would produce an internal condensation whenever steam entered it, and which would be repeated every stroke; this I proposed to remedy by *an external cylinder containing steam, surrounded by another of wood, or of some other substance which would conduct heat slowly.*

Fig. 35.



“When once the idea of the *separate condensation* was started, all these improvements followed as corollaries in quick succession, so that in the course of one or two days, the invention was thus far complete in my mind, and I immediately set about an experiment to verify it practically. I took a large brass syringe A, one and three-fourth inches diameter, and ten inches long, made a cover and bottom to it of tin-plate, with a pipe S to convey steam to both ends of the cylinder from the boiler; another pipe E to convey steam from the upper end to the condenser (for, to save apparatus, I inverted the cylinder.) I drilled a hole longitudinally through the axis of the stem of P the piston, and fixed a valve at its lower end, to permit the water which was produced by the condensed steam, on first filling the cylinder, to issue. The condenser used upon this occasion consisted of two pipes *a b, c d* of thin tin-plate, ten or twelve inches long, and about one-sixth inch diameter, standing perpendicular, and communicating at top with a short horizontal pipe *h* of large diameter, having an aperture on its upper side which was shut by a valve opening upwards. These pipes were joined at bottom to another perpendicular pipe *p* of about an inch diameter, which served for the air and water pump; and both the condensing pipes and the air-pump were placed in a small cistern C filled with cold water.

“The steam-pipe was adjusted to a small boiler B. When steam was produced, it was admitted into the cylinder, and soon issued through the perforation of the rod, and at the valve of the condenser. When it was judged that the air was expelled, the steam-cock was shut, and the air-pump piston-rod was drawn up, which leaving the small pipes of the condenser in a state of vacuum, the steam entered them and was condensed. The piston of the cylinder immediately rose and lifted a weight of about eighteen pounds, which was hung to the lower end of the piston-rod. The exhaustion-cock was shut, the steam was re-admitted into the cylinder, and the operation was repeated; the quantity of steam consumed,

and the weights it could raise were observed; and, excepting the non-application of the steam-case and external covering, the invention was complete, in so far as regarded the savings of steam and fuel. A large model, with an outer cylinder and wooden case, was immediately constructed, and the experiments made with it served to verify the expectations I had formed, and to place the advantage of the invention beyond the reach of doubt. It was found convenient afterwards to change the pipe-condenser for an empty vessel, generally of a cylindrical form, into which an injection played, as in fig. 36, and in consequence of there being more water and air to extract, to enlarge the air-pump.

“The change was made, because, in order to procure a surface sufficiently extensive to condense the steam of a large engine, the pipe-condenser would require to be very voluminous, and because the bad water with which engines are frequently supplied, would crust over the thin plates, and prevent their conveying the heat sufficiently quick. The cylinders were also placed with their mouths upwards, and furnished with a working-beam, and other apparatus, as was usual in the ancient engines; the inversion of the cylinder or rather of the piston-rod, in the model, being only an expedient to try more easily the new invention, and being subject to many objections in large engines.

“In 1768 I applied for letters patent for my ‘Methods of Lessening the consumption of Steam, and consequently of Fuel, in Fire-Engines,’ which passed the Seals in January 1769; and my specification was enrolled in Chancery in April following, and was as follows:—

“My method of lessening the consumption of steam, and consequently fuel, in fire-engines, consists of the following principles:—

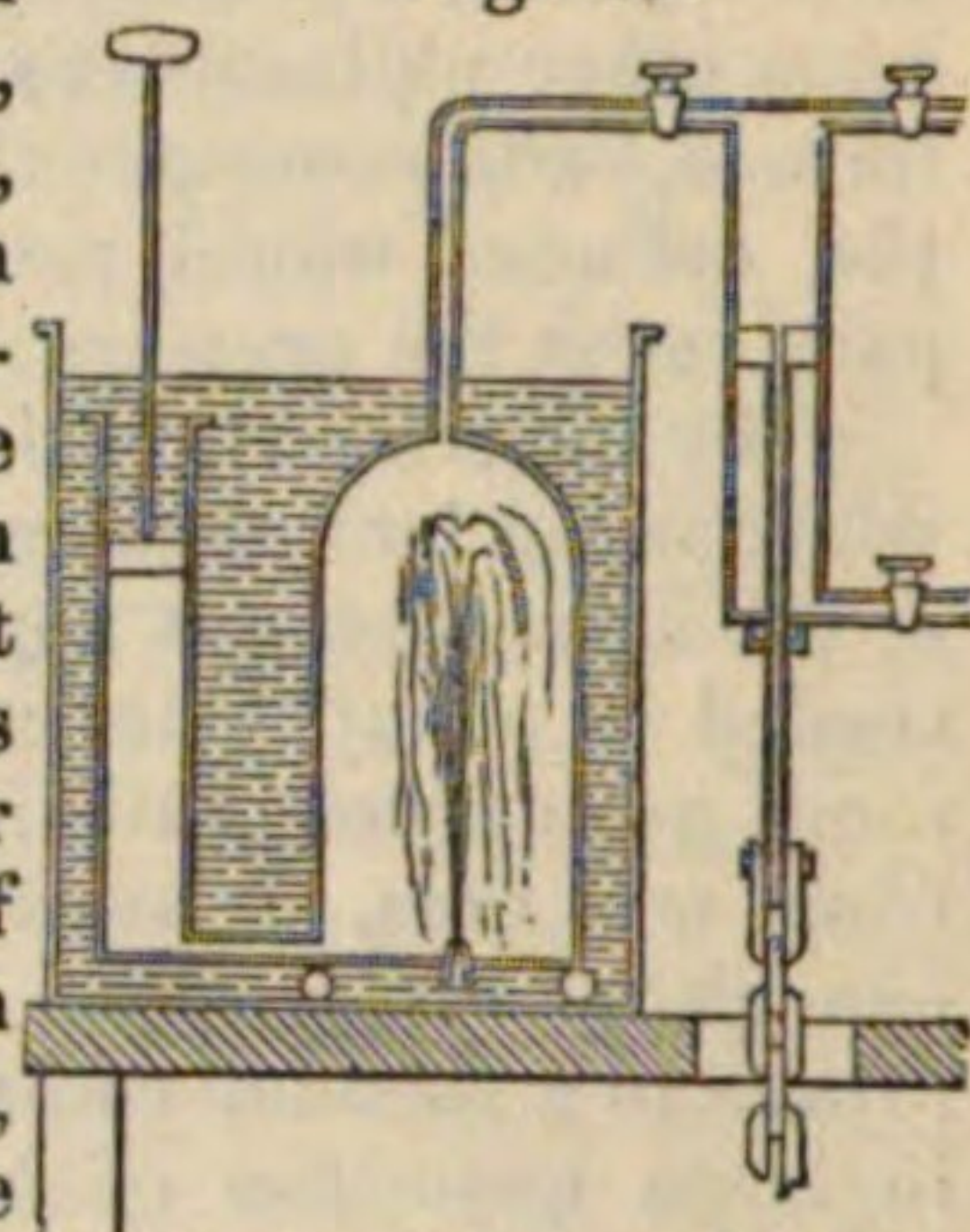
“First, That vessel in which the powers of steam are to be employed to work the engine, which is called the cylinder in common fire-engines, and which I call the steam-vessel, must, during the whole time the engine is at work, be kept as hot as the steam that enters it; first, by enclosing it in a case of wood, or any other materials that transmit heat slowly; secondly, by surrounding it with steam or other heated bodies; and, thirdly, by suffering neither water or any other substance colder than the steam, to enter or touch it during that time.

“Secondly, In engines that are to be worked wholly or partially by condensation of steam, the steam is to be condensed in vessels distinct from the steam-vessels or cylinders, although occasionally communicating with them; these vessels I call condensers; and, whilst the engines are working, these condensers ought at least to be kept as cold as the air in the neighbourhood of the engines, by application of water, or other cold bodies.

“Thirdly, Whatever air or other elastic vapour is not condensed by the cold of the condenser, and may impede the working of the engine, is to be drawn out of the steam-vessels or condensers by means of pumps, wrought by the engines themselves, or otherwise.

“Fourthly, I intend, in many cases, to employ the expansive force of steam to press on the pistons, or whatever may be used instead of them, in the same manner as the pressure of the atmosphere is now employed in common fire-engines. In cases where cold water cannot be had in plenty, the engines may be wrought by this force of steam only, by discharging the steam into the open air after it has done its office.

Fig. 36.



Steam-Engine.

Watt's History of his own Improvements.

Steam-Engine.

Watt's History of his own Improvements.

Illustrations of Watt's Improvements.

"Lastly, Instead of using water to render the piston or other parts of the engines air and steam tight, I employ oils, wax, resinous bodies, fat of animals, quicksilver, and other metals, in their fluid state.

"And the said James Watt, by a memorandum added to the said specification, declared, that he did not intend that any thing in the fourth article should be understood to extend to any engine where the water to be raised enters the steam-vessel itself, or any vessel having an open communication with it."

Such is Mr Watt's simple account of his beautiful invention—the condenser or refrigerator, which is the characteristic member of the modern steam-engine. The fire-engine of Newcomen possessed only two principal members, to which all the other parts may be considered as mere appendages. The modern steam-engine of Watt consists of three principal members. The two members of Newcomen's engine are the generating apparatus, by which the steam is produced from the water and conveyed to the second member, or the apparatus of application, where the elastic force of the steam is brought in contact with the piston in the cylinder, so as to produce the motion required for the mechanical effect of the machine, and thus directly applied to the work to be done. The third member, added by Watt, is a refrigerator or condensing apparatus, perfectly separate from and independent of the other two, for reconverting the steam, after it has done its duty in filling the cylinder, into the liquid from which it had been originally formed. We have, then, the boiler or generator with its appendages, the cylinder or applicator with its appendages, and the refrigerator or condenser with its appendages,—the function to be discharged by the first of these being altogether the reverse of the last; the first producing steam by heat from water, the last producing water from steam by cooling.

The progress of improvement in the steam-engine may be very well illustrated by comparison with an early project of Dr Papin, who, although he contributed no part

Fig. 37.

Papin's Apparatus

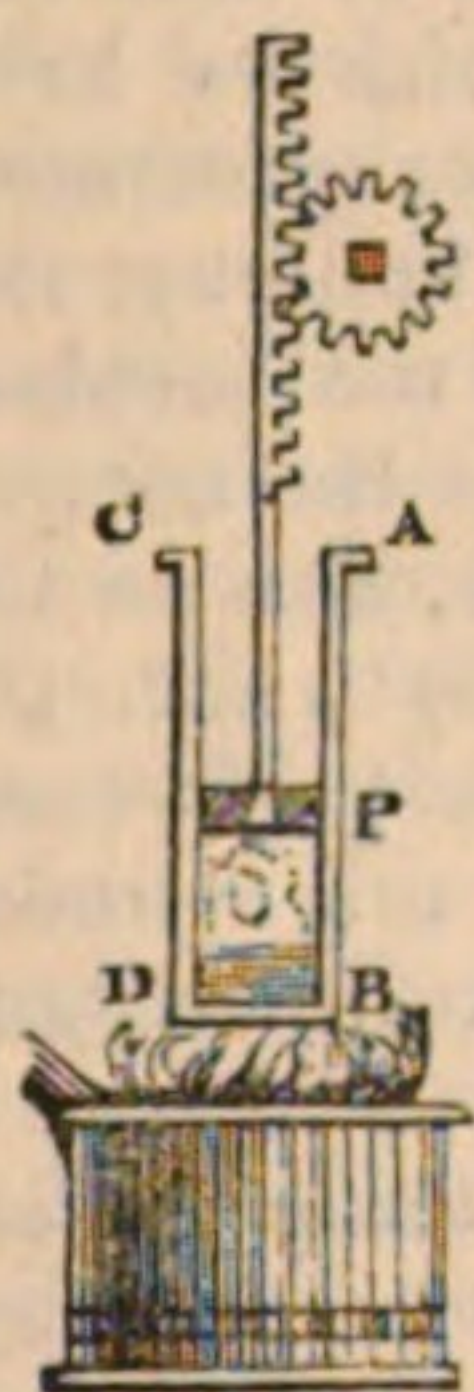
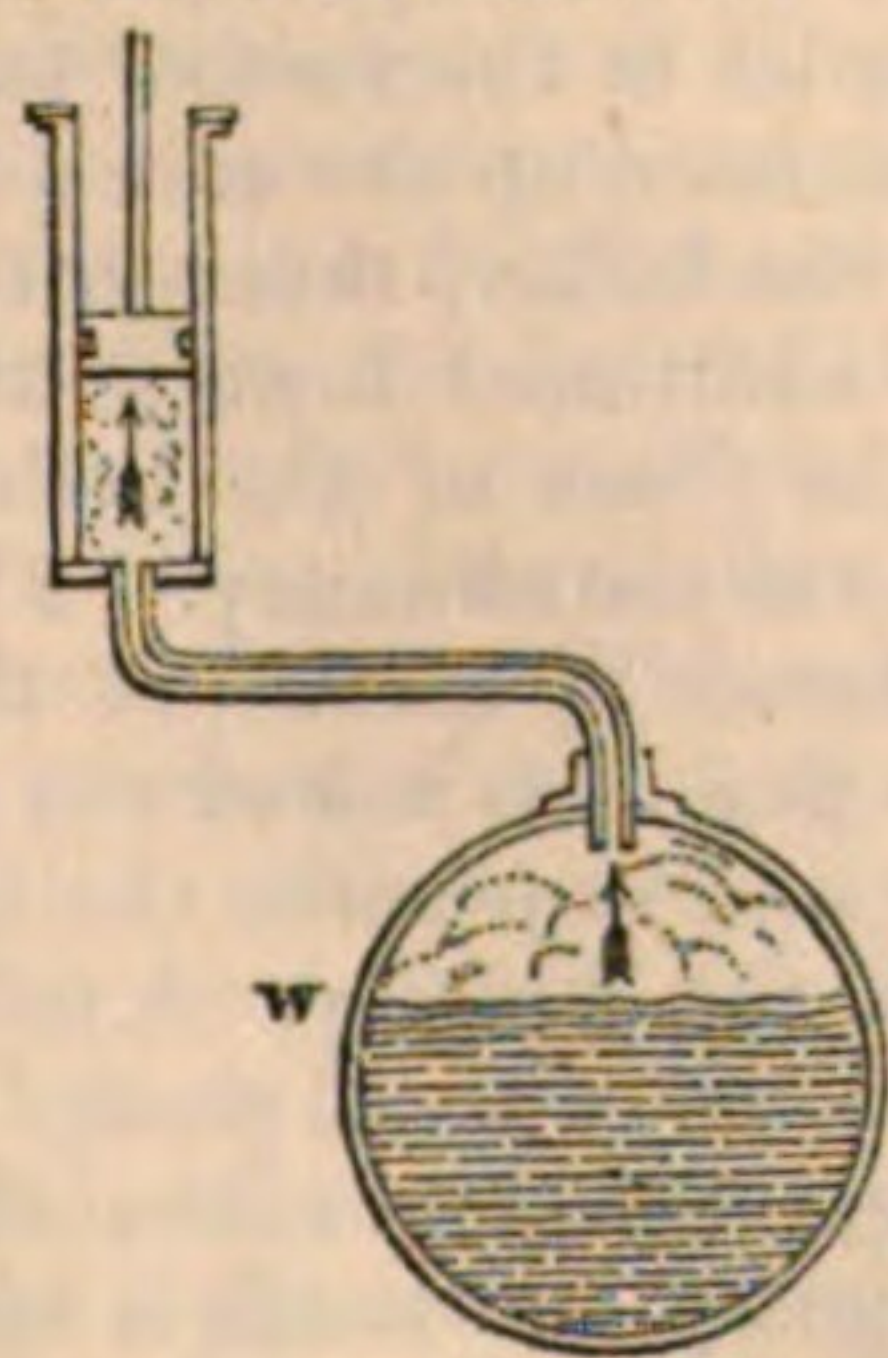


Fig. 38.

Newcomen's Apparatus.



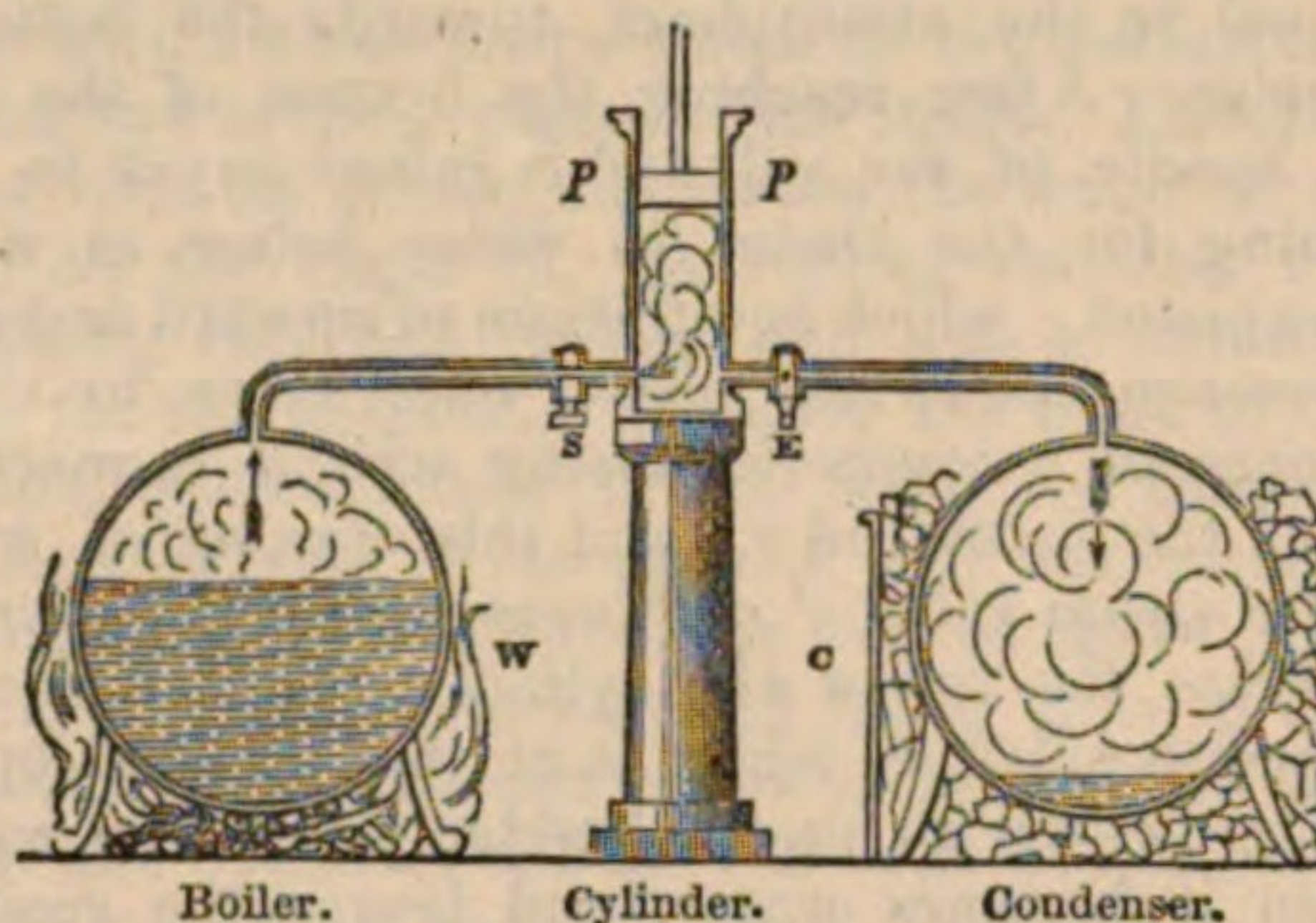
towards the production of the modern steam-engine, nevertheless exercised his ingenuity curiously, though fruitlessly, upon the project of deriving mechanical power from the motion of a piston in a cylinder, first of all by gunpowder, and afterwards by steam. In Papin's project, fig. 37, he takes a cylinder, A B C D, containing a piston P, below which he places a fire, so as to generate steam from a little water in the bottom of the cylinder. This steam raises the piston, and it is evident that on the fire being removed, steam will be condensed, and the piston will again be carried to the bottom. Comparing this rude project, in which the steam is alternately produced and recondensed in the cylinder itself, which is

alternately warmed and chilled, with the engine of Newcomen, fig. 38, we observe the following important change. The calcification of the water and generation of steam are carried on in a boiler, W now removed to a considerable distance from and totally unconnected with the cylinder, except by a pipe of communication opened and shut alternately. Still, however, we have the process of cooling and condensation wholly carried on in the cylinder itself, by means of a jet of cold water

playing therein. But let us now make a third step, and we arrive at the model of a machine acting on the principle of Mr Watt's, fig. 39. As we have already, in the machine of Newcomen, a separate heating apparatus, W, conducting the steam in a highly rarefied state to the cylinder, so now let us have a vessel, C, placed on the other side, and let this vessel have first been rendered empty or perfectly vacuous by expelling and pumping out the air; and let us also, for the sake of experiment, put a few lumps of ice and salt in the inside and on the outside of this vessel, surrounding it on every side; and we shall have a refrigerator as a counterpart to the boiler, and a type of the improvement of Watt.

Steam-Engine.

Fig. 39.

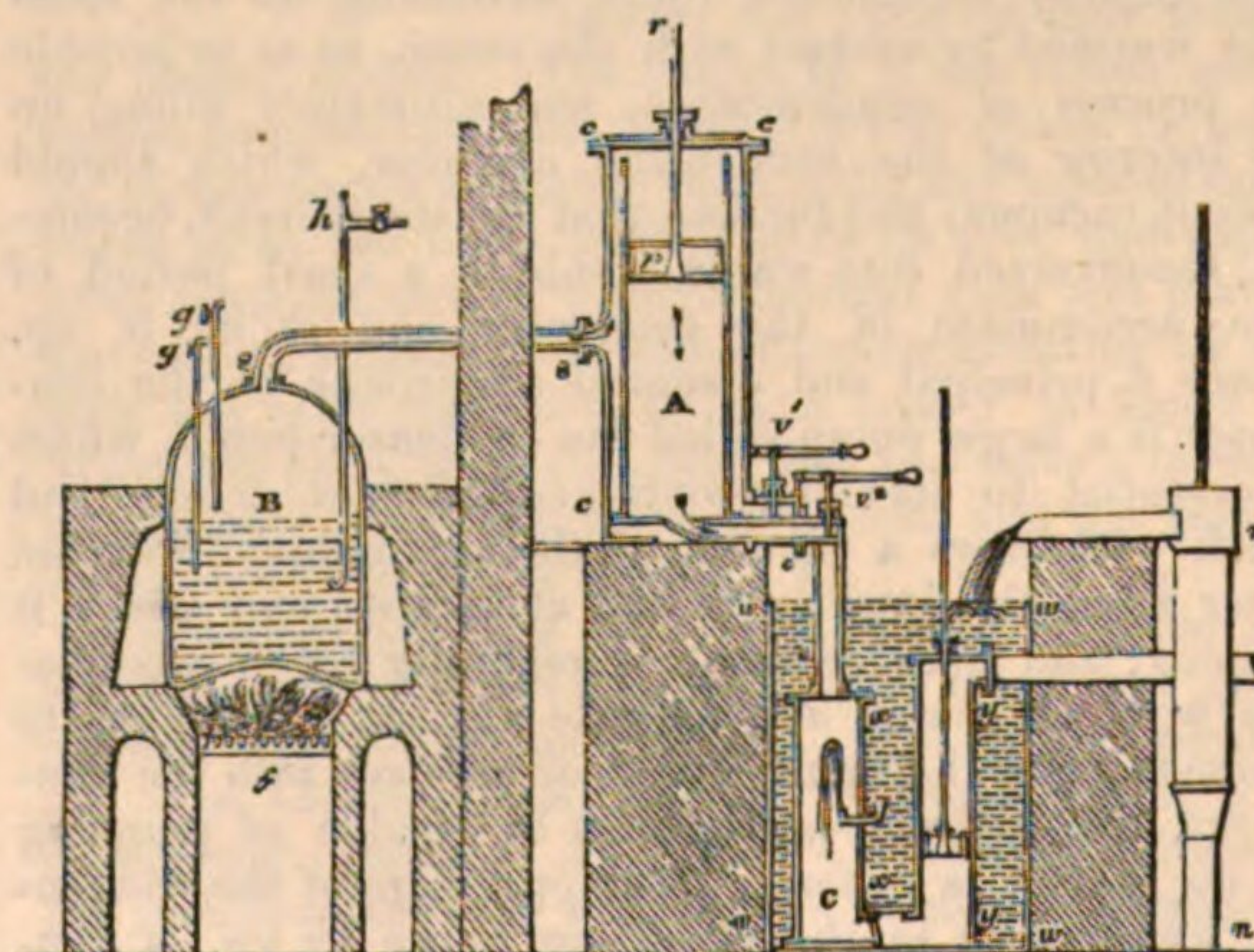


If we now open the stopcock S, the steam generated in the boiler will rush into the cylinder, pressing the piston upwards; and if the stopcock E be next opened, the steam in E having been previously shut, the steam in E will instantly escape into the vacuum in the refrigerator, and being condensed into less than a thousandth part of its bulk, will leave the cylinder vacuous. Thus the motion of the piston upwards and downwards is effected by the inventions of Newcomen and Watt, without either applying the fire or the cold directly to the cylinder in which the power is given out. Thus the loss of more than fifty per cent is remedied by the separate condenser of Watt. Papin's scheme was possible but not practicable; Newcomen's was practicable but wasteful. Watt's engine is practical, economical, and complete, both in theory and in practice, as it renders available all the power of heat which the steam contains, with the exception only of the very small part consumed in giving motion to the machine itself.

The following figure (40) approaches very closely to the form of Mr Watt's first engines. Their details are as follows. In the diagram, A represents the cylinder of his earlier engine, B the boiler, and C the condenser, each with its various appendages. The appendages of the boiler B, are of course, f, the furnace in which the

Details of Watt's Improved Steam Engine.

Fig. 40.



Steam-Engine.

Details of Watt's improved Steam Engine.

fuel is burned; *g g*, small pipes for showing the height of the water in the boiler; *h*, a pipe for supplying the boiler with water as its contents pass off in the form of steam; *s s*, a steam-pipe for the purpose of conveying the steam to the top of the cylinder. The appendages of the cylinder are, *p* the piston, fitting accurately the inside of the cylinder, surrounded with hemp packing, soaked with tallow and oil, so as to be steam-tight; the casing, *c c c c*, which excludes the cold air of the atmosphere from entering into the cylinder to cool it down at the expense of afterwards heating it by the steam; and, instead of allowing it to enter at the top of the cylinder at *A*, and press down the piston, as in Newcomen's engine, the hot steam is substituted, which, being of an elasticity equal to the atmosphere, presses it, with a force equal to the atmosphere, towards the bottom of the cylinder. After reaching the bottom of the cylinder, the handle of the valve *v*¹ is raised so as to make an opening for the steam to enter below as well as above the piston; which equilibrium of upward and downward pressure allows the piston once more to rise, in consequence of a counterbalancing weight connected to the top of the piston-rod *r*; and this opening of what is called the steam-valve *v*¹ continues until the piston once more reaches the top of the cylinder, when it is closed. The eduction valve *v*², which is at that moment opened, permits the steam to escape suddenly into the condenser, when it becomes water, and leaves the space below the cylinder vacuous, so as to give free space for the piston to be carried down into the cylinder by the pressure of the steam resting always on the top of the piston. These, the casing, piston, piston-rod, steam-valve, eduction-valve, and communicating passages, are appendages of the second great member of the machine, the cylinder, by which the power of the steam is applied to give the required motion to whatever solid machinery may be placed in connexion with the piston-rod. The appendages of the condenser *C* of Mr Watt are as follows. First of all, a large cistern, *w w w w*, of cold water is provided, and furnished continually with fresh supplies of cold water either from a running stream or by means of a pump *m n*, wrought by the engine itself. In this is placed the condensing chamber *C x x*, wholly surrounded by the cold water, but perfectly empty, excepting that a small jet of cold water from the exterior is admitted through a regulated aperture to play in the inside, by which injection it has always been observed that the condensation of the steam is more efficient than when a casing of metal intervenes between the cold water and the steam. The eduction-pipe *e e e*, conducts the steam out of the cylinder by the valve *v*² into the condenser *x x*, where it is reduced back into the water from which it had been originally generated. Now, it must be obvious on a little consideration, that the water which is injected into the condenser must rapidly accumulate there, becoming at the same time warmed by contact with the steam, so as to impede the process of condensation, and ultimately filling up the interior of the condensing chamber, which should be kept vacuous; and further, that the steam itself, becoming reconverted into water, would in a short period of time accumulate in the condenser and choke it up. Hence a principal and essential appendage of the condenser is a large pump called the condenser-pump, which is essential to its long-continued efficient action, and which withdraws a portion of the accumulated warmed water from the interior of the condenser, and keeps it vacuous; and because there is generally air in combination with the water, and because also air is very apt to insinuate itself by many chinks or crevices into the condenser, this clearing-pump must be capable of pumping out air as well as water. This appendage of the condenser, represented in the preceding figure by *yy*, is gen-

erally termed the "air-pump;" a name which imperfectly expresses the functions of the said condenser-pump.

Fire being placed under the boiler, its heat, communicated to the water, rapidly expands that water, and rarefies it into steam, by the addition of six times more than its usual supply of heat. This combination of heat and water, forming the steam, rushes along the steam-pipe into the cylinder casing, and is admitted into the interior of the machine, filling all its chambers and pipes with steam; but that portion of the steam which is in communication with the condenser being instantly chilled by the jet of cold water and the cold sides of the vessels in the cold well, is condensed, and then the valve *v*² being closed so as to admit no more steam into the condenser, and the valve *v*¹ closed so as to admit no more steam into the lower part of the cylinder below the piston, there remains the elastic force of the steam above, pressing it towards the bottom of the cylinder with a force proportioned to the pressure of the steam and the extent of the cylinder. Thus a moving power is generated in the cylinder by the steam, which may be conveyed through the piston-rod *r*, and applied through various mechanism of application to the performance of the required work. The steam which has thus pressed down the piston is now admitted below to neutralize the force of that which remains; and having thus done its duty, is once more annihilated by the opening of the communication into the condenser, into which it rushes, and being almost instantly deprived of the caloric which gave it power and magnitude, there remains nothing except the few spoonfuls of water from which all that volume of steam had arisen, now lying inert at the bottom of the cylinder. This dead water is not yet cold. It is evident that in the primary generation of steam in the boiler, the supply of water must be rapidly diminished by this boiling off, and that this water must somehow be supplied. Now here lies an improvement: this waste, instead of being supplied by cold water, may be better replenished with the water of the condenser, which is highly heated in condensing the steam from the cylinder.

Mr Watt's Engine was first used as a substitute for the engine of Newcomen in pumping up water or draining mines: in 1788 it had attained the form which we have given in the following figure. The engine is represented in fig. 41 as contained within the walls of a building, the anterior portion of which is removed to show the machine. The boiler stands on the left of the figure, on the outside of the building; and on the right of the figure, also on the outside of the house, are the large pumps, by which the water is raised, and the work of the engine performed. Nearly in the centre of the building stands the cylinder with its appendages, and below these are the cold well and condensing apparatus.

Beginning with the apparatus for generating steam; on the left of the figure, *H* is the boiler, of what is called the waggon shape, set in a furnace of brick-work immediately over the fire, which rests on the fire-bars at *p*, leaving a very deep ash-pit below; the flame passes away under the concave bottom of the boiler to the further end, and there, instead of proceeding at once up the chimney, returns by *o* on the left side of the boiler, through the brick channel or flue, giving out additional heat to the water, and after passing across the front of the boiler, proceeds along the right-hand flue *o* to the chimney. The draught of the chimney is regulated by means of the damper *r*, which descends into the flue or is raised out of it in any degree by the attendant, and so permits the air to rush with greater or less ease up the chimney. A tube *t*, regulated by a stopcock, comes from a small pump *U* on the right-hand side of the figure, which raises the warm water discharged by the air-pump, and sends it into the boiler so as to replenish its waste; this pipe and pump

Steam-Engine.

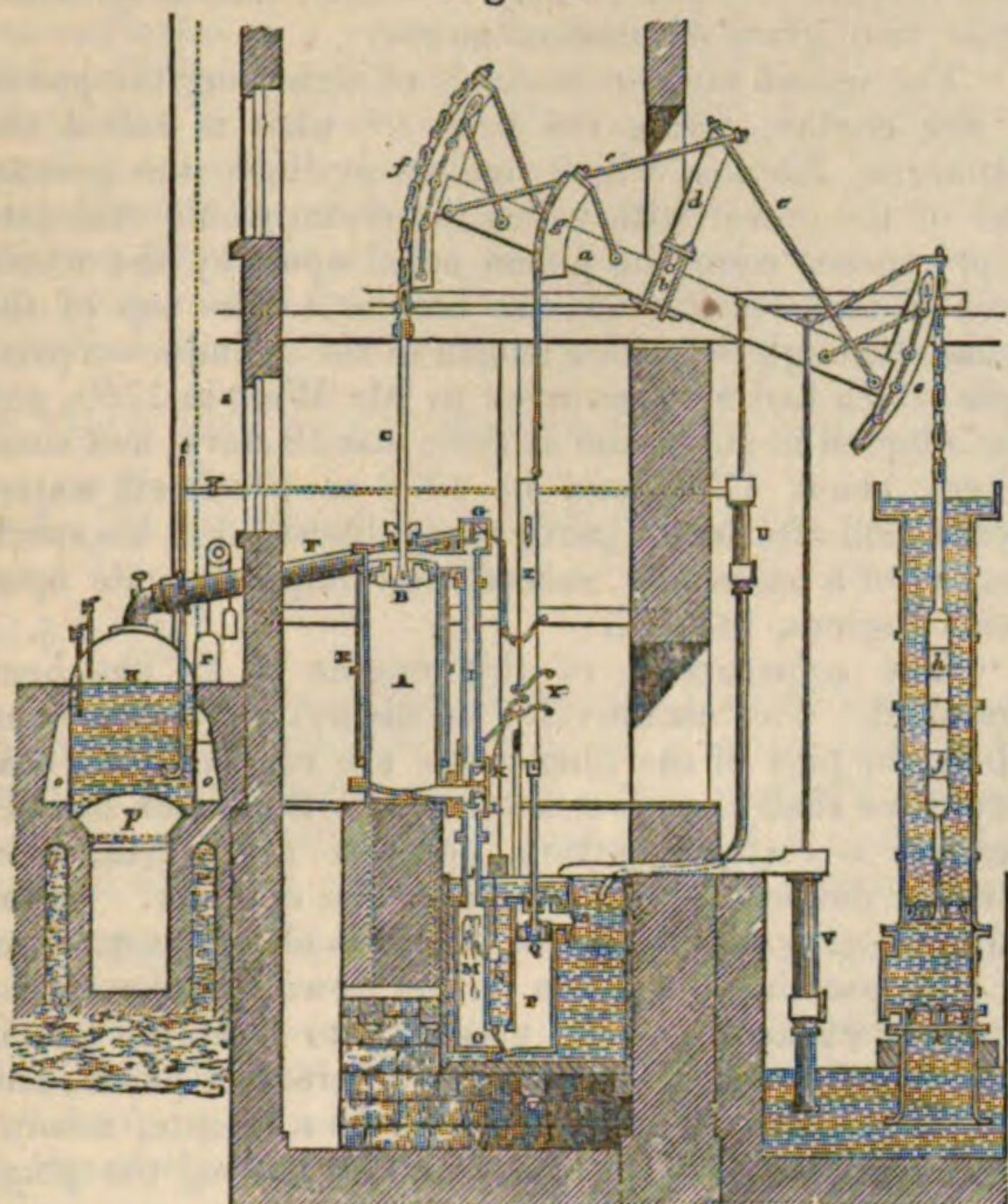
General View of Watt's Steam Engine.

Watt's Pumping Engine of 1768.

Steam-Engine. being generally named the feed-pipe and tube. The two little tubes proceeding from the water in the

Fig. 41.

Descrip-
tion of Mr
Watt's En-
gine.

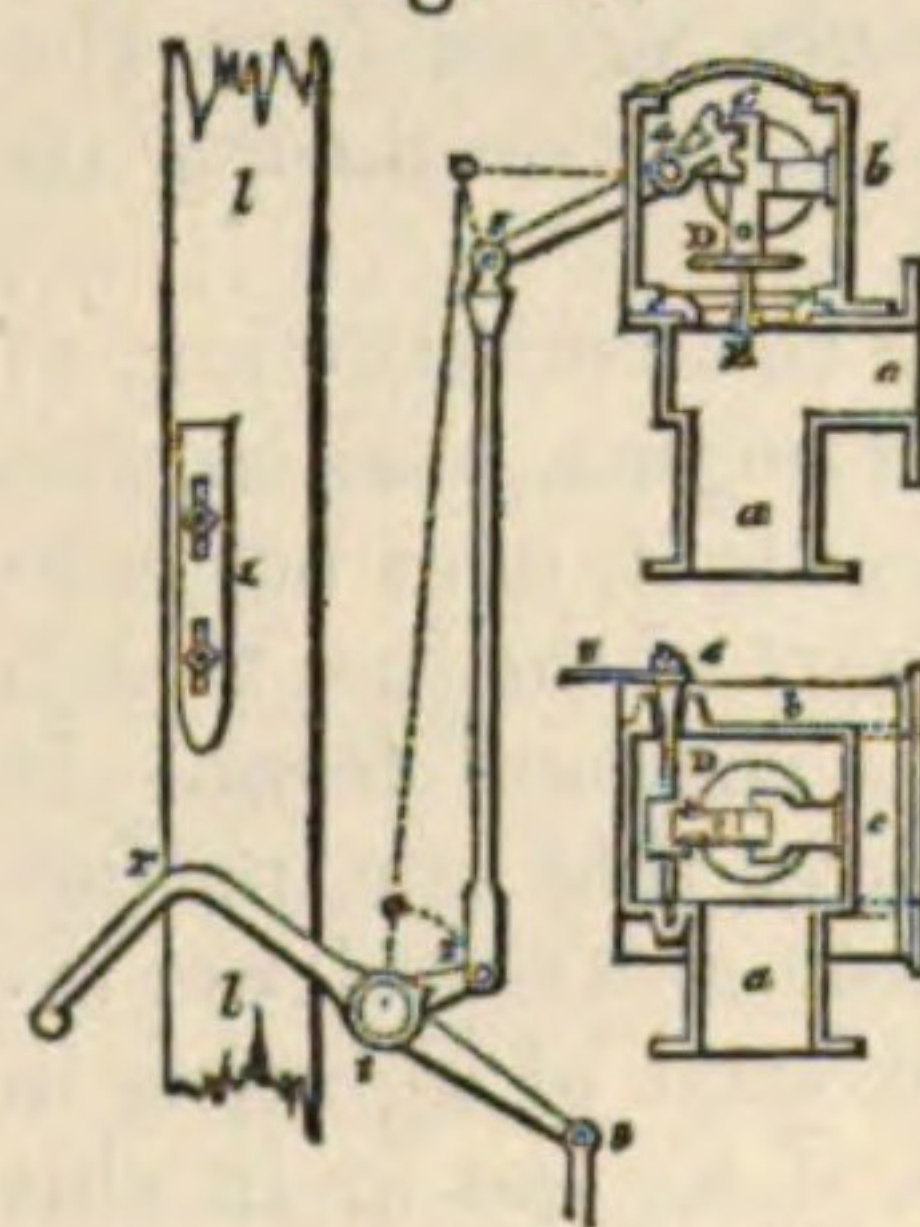


boiler, are slender pipes open at both ends, and have external stopcocks, which are always shut except when the attendant wishes to ascertain the height of the water in the boiler, when he opens these gauge-cocks and observing whether water or steam issues from them, forms his judgment accordingly. F is the steam-pipe, which carries the steam away from the boiler to be applied to its useful effect in the second great member of the engine.

The second great member of the machine is placed in the engine-house. A is the working cylinder, in which is contained the moving piston B, which communicates the force impressed on it by the steam, through the piston-rod c, and the chain f, to the end of the great lever or working-beam, f a e, which is forced up and down around the fixed centre or iron gudgeon b, and so raises or depresses the other end of the lever on the right-hand side of the figure, and thus gives the required motion to h, j, the piston and rods in the barrel of the great pump, in which the work of raising water to a height or from a mine is the useful labour or duty to be performed by the engine. Returning to the cylinder at A, we have now to examine the mechanism by means of which the steam is admitted alternately above and below the piston, through the openings or ports which may be observed on the right-hand side of the cylinder at top and bottom. F is the steam-pipe which brings steam from the boiler to the top of the valve passages, and the pipe I conducts it down to the bottom valves and port at K, and the pipe J forming the eduction-pipe, conducts the steam into the refrigerating apparatus, where it is finally condensed. In commencing to work the machine, the duty of the attendant is to allow the steam to pass freely into all the pipes, passages, and ports, F G I J, &c. filling the cylinder A, the condenser M, and passing out at an aperture O, closed by a valve called the blow-off valve; by means of which operation, the whole of the parts being filled with steam, are rendered vacuous from air, and this preparatory process is called blowing through. At G it is to be observed that there is a steam-nozzle and valve or regulator, which allows the steam to enter the cylinder at the upper part whenever it is opened, by raising the metallic cover or valve from the open-

ing of the nozzle immediately below, which it exactly fits. At K is a similar nozzle and valve called the equilibrium-valve and nozzle, which admits steam through the pipe I into the bottom part of the cylinder; and the third or exhaustion-valve and nozzle or aperture, allows the final egress of the steam into the condenser. After the engine has been wholly filled with steam, the piston B, being at the top of the cylinder, the injection-cock N is suddenly opened, and the cold *jet d'eau* playing amongst the steam condenses it instantaneously, forming a vacuum into which the steam from the cylinder instantly rushes, and is in like manner annihilated, leaving the cylinder below the piston equally vacuous; and of course the steam from the boiler, on being admitted by the valve G to the upper side of the piston, instantly presses it down into the vacuum below with a force proportional to the perfection of that vacuum and to the pressure of the steam. Thus the engine makes its first stroke and raises the water of the great pump on the right of the figure, and the weight of the chain, rod, and bucket, and also a counterpoise h, added for the purpose of restoring the beam to its former position, which it does in the following manner. The equilibrium-valve K is opened, and the steam getting admission below the piston, as well as above it, ceases to urge it in either direction, and being thus in equilibrio, the piston would remain passively in its place at the bottom of the cylinder, but the action of the counterpoise h, and the weight of the water and pump-rods in the large pump on the outside, draw down the outer end of the great lever or working-beam f a e, and so raise the interior end f, and the piston B to the top of the cylinder. The equilibrium-valve is then closed at K, and the eduction-valve L is opened, so as to allow the steam below the piston to rush down into the condenser and leave a vacuum under the piston, into which it is immediately forced down by the pressure of the steam above A as at first, and raising water at the other end of the beam through a second stroke; and, thus by the continual opening and shutting of the valves by the attendant, the engine performs its work. But we have still to consider the mechanism by which the valves are shut and opened, and the machine is made to shut and open its own valves.

Fig. 42.



the proper instant. The valves D E are called conical valves, because the small cover D which closes the opening of each nozzle under the valve is slightly tapered downwards so as the more readily to fit its seat, and each is lifted from its seat by a small toothed rack and pinion c moved by a spindle from without, communicating by rods with the valve gear at r, or at Z and Y in figure 41. When the plug-frame l i l descends, the valve d is closed by the plug i, and the valve K is shut, and the valve L in figure 41 opened by the plug Y.

Returning to figure 41, it will be seen that the condensing apparatus and its appendages are placed almost immediately under the cylinder, and to the right of it. The eduction-pipe J conducts the steam into the condensing chamber M. This chamber is placed in the middle of the cold well, so as to be wholly surrounded

Steam-
Engine.

Mr Watt's
Pumping-
Engine of
1768.

Steam-Engine.

Description of Mr Watt's Engine of 1788.

by cold water; and through the regulated aperture N a jet of cold water is allowed to play in the inside of it amongst the steam. P the air-pump is also placed in the cold well surrounded by water; Q the piston or bucket of the air-pump is worked up and down by the piston-rod Q Y Z *g* from the great lever. The valve R closes when the piston descends, and opens on its ascent, allowing water and air to pass into the air-pump, but preventing its return; and the upper valve of the air-pump S allows the escape of water and air outwards, but prevents its return; this valve S leads to the hot well T, from which the feed-pump U draws off a supply of water for the boiler.

Robison's Description of Watt's Engine.

"The great advantage of Mr Watt's form is the almost total annihilation of the waste of steam by condensation in the cylinder. The cylinder is always hot, and therefore perfectly dry. This must be evident to any person who understands the subject. By the time that Mr Watt had completed these improvements, his experiments on the production of steam had given him a pretty accurate knowledge of its density: and he found himself authorized to say, that the quantity of steam employed did not much exceed what would fill the cylinder, so that very little was unavoidably wasted. But before he could bring the engine to this degree of perfection, he had many difficulties to overcome. He inclosed the cylinder in another containing steam, and that in a wooden case at a small distance from it, which effectually prevents all condensation in the inner cylinder from external influence; and the condensation by the outer cylinder itself, which was very small, had no other bad consequence than the loss of so much steam as formed the condensed water.

"The greatest difficulty was to make the great piston tight. The old and effectual method, by water lying on it, was inadmissible. He was therefore obliged to have his cylinders most nicely bored, perfectly cylindrical, and finely polished; and he made numberless trials of different soft substances for packing his piston, which should be tight without enormous friction, and which should long remain so, in a situation perfectly dry and very hot.

"After all that Mr Watt has done in this respect, he thinks that the greatest part of the waste of steam which he still perceives in his engines, arises from the unavoidable escape by the sides of the piston during its descent.

"But the fact is, that an engine of this construction, of the same dimensions with a common engine, making the same number of strokes of the same extent, does not consume above one-fourth or one-third part of the fuel that is consumed by the best engines of the common form. It is also a very fortunate circumstance, that the performance of the engine is not immediately destroyed, nor indeed sensibly diminished, by a small want of tightness in the piston. In the common engine, if air get in in this way, it immediately puts a stop to the work; but although even a considerable quantity of steam get past the piston during its descent, the rapidity of condensation is such, that hardly any diminution of pressure can be observed.

"When Newcomen's engines are working under loads inferior to their whole power, they are regulated to prevent shocks which would be prejudicial, by lessening the quantity of injection, or by shutting the injection-cock sooner. These new engines may, in some degree, be regulated in the same manner; but it is done more effectually and economically, first, by limiting the opening of the regulating-valve which admits the steam above the piston, and letting it continue so far open during the whole length of the stroke; secondly, by letting it open

fully at first, and shutting it completely when the piston has proceeded downwards only part of its stroke; or, lastly, by the use of a throttle-valve, which, acting in the same manner as the floodgate of a mill, admits no more steam than gives the desired power.

"The second of these methods of regulating the power of the engine, forms the basis of what is called the *Expansive Engine*, which renders available the greater part of the power with which the steam would rush into empty space, were the piston acted upon by the whole force of the steam, from the bottom to the top of the stroke, through the whole length of the cylinder—a principle which had first occurred to Mr Watt in 1769, and was adopted in an engine at Soho manufactory, and some others, about 1776, and in 1778 at Shadwell water-works, and afterwards particularly described in his specification of a patent for several new improvements upon steam-engines, in 1782.

"The construction of this engine is as has been described. The steam-valve is always allowed to open fully; the pins of the plug-frame are regulated so, that that valve shall shut the moment that the piston has descended a certain portion, suppose one-fourth, one-third, or one-half, of the length of the cylinder. So far the cylinder was occupied by steam as elastic as common air. In pressing the piston farther down, it behoved the steam to expand, and its elasticity to diminish. It is plain that this can be done in any degree we please, and that the adjustment can be varied in a minute, according to the exigency of the case, by moving the plug-pins.

"In the mean time, it must be observed, that the pressure on the piston is continually changing, and consequently the accelerating force. The motion, therefore, will no longer be uniformly accelerated. It will approach much faster to uniformity; nay, it may be retarded, because although the pressure on the piston at the beginning of the stroke may exceed the resistance of the load, yet when the piston is near the bottom, the resistance may exceed the pressure. Whatever may be the law by which the pressure on the piston varies, an ingenious mechanic may contrive the connecting machinery in such a way that the chains or rods at the outer end of the beam shall continually exert the same pressure, or shall vary their pressure according to any law he finds most convenient. It is in this manner that the watchmaker, by the form of the fuzee, produces an equal pressure on the wheel-work by means of a very unequal action of the main-spring. In like manner, by making the outer arch-heads portions of a proper spiral instead of a circle, we can regulate the force of the beam at pleasure.

"Thus we see how much more manageable an engine is in this form than Newcomen's was, and also more easily investigated in respect of its power in its various positions. The knowledge of this last circumstance was of mighty consequence, and without it no notion could be formed of what it could perform, which may be called a discovery of great importance in the theory of the engine. We shall give here Mr. Watt's theory of the expansive engine which we have just described.

"Let ABCD (Fig. 43.) represent a section of the cylinder of a steam-engine, and EF the surface of its piston. Let us suppose that the steam was admitted while EF was in contact with AB, and that as soon as it had pressed it down to the situation EF, the steam-cock is shut. The steam will continue to press it down, and as the steam expands, its pressure diminishes. We may express its pressure (exerted all the while the piston moves from the situation AB to the situation EF) by the line EF. If we suppose the elasticity of the steam

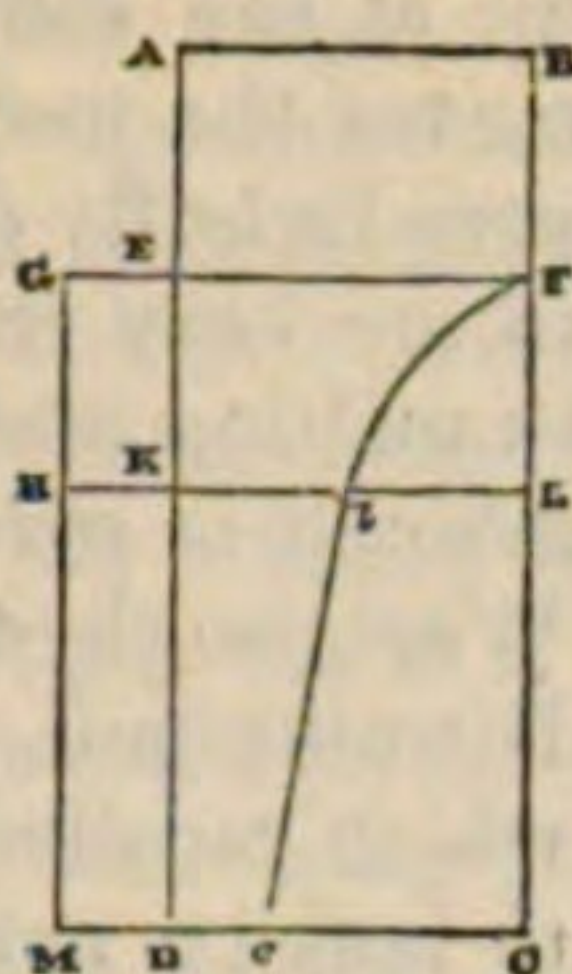
Steam-Engine.

Mr Watt's Engine Working Expansively, as described by Robison.

Steam-Engine.
Mr Watt's Expansive Engine.

proportional to its density, as is nearly the case with air, we may express the pressure on the piston in any other position, such as KL or DC, by Kl and Dc , the ordinates of a rectangular hyperbola $F l c$, of which AE AB are the asymptotes, and A the centre. The accumulated pressure during the motion of the piston from EF to DC , will be expressed by the area $EF c DE$, and the pressure during the whole motion by the area $ABF c DA$.

Fig. 43.



"Now it is well known that the area $EF c DE$ is equal to $ABFE$ multiplied by the hyperbolic logarithm of $\frac{AD}{AE}$,

$$= L \cdot \frac{AD}{AE}$$
 and the whole area $ABF c DA$ is $= ABFE \times (1 + L \cdot \frac{AD}{AE})$.

"Thus let the diameter of the piston be 24 inches, and the pressure of the atmosphere on a square inch be 14 pounds; the pressure on the piston is 6333 pounds. Let the whole stroke be 6 feet, and let the steam be stopped when the piston has descended 18 inches, or 1.5 feet. The hyperbolic logarithm of $\frac{6}{1.5}$ is 1.3862943.

Therefore the accumulated pressure $ABF c DA$ is $= 6333 \times 2.3862943 = 15112$ pounds.

"As few professional engineers are possessed of a table of hyperbolic logarithms, while tables of common logarithms are, or should be, in the hands of every person who is much engaged in mechanical calculations, let the following method be practised. Take the common logarithm of $\frac{AD}{AE}$, and multiply it by 2.3026; the product is

the hyperbolic logarithm of $\frac{AD}{AE}$.

"The accumulated pressure while the piston moves from AB to EF is 6333×1 , or simply 6333 pounds. Therefore the steam while it expands into the whole cylinder adds a pressure of 8781 pounds.

"Suppose that the steam had got free admission during the whole descent of the piston, the accumulated pressure would have been 6333×4 , or 25332 pounds.

"Here Mr Watt observed a remarkable result. The steam expended in this case would have been four times greater than when it was stopped at one-fourth, and yet the accumulated pressure is not twice as great, being nearly five-thirds. One-fourth of the steam performs nearly three-fifths of the work, and an equal quantity performs more than twice as much work when thus admitted during one-fourth of the motion.

"This is curious and important information, and the advantage of this method of working a steam-engine increases in proportion as the steam is sooner stopped; but the increase is not great after the steam is rarefied four times. The curve approaches near to the axis, and small additions are made to the area. The expense of such great cylinders is considerable, and may sometimes compensate this advantage.*

"It is very pleasing to observe so many unlooked-for advantages resulting from an improvement made with the sole view of lessening the waste of steam by condensation. While this purpose is gained, we learn how to husband the steam which is not thus wasted. The engine becomes more manageable, and is more easily adapted to every variation in its task, and all its powers are more easily computed.

* All these calculations, however, proceed upon the supposition that steam contracts and expands by variations of pressure, in the same ratios that air would do.

Let the steam be stopped at	Its performance is mult.
$\frac{1}{2}$	1.7
$\frac{1}{3}$	2.1
$\frac{1}{4}$	2.4
$\frac{1}{5}$	2.6
$\frac{1}{6}$	2.8
$\frac{1}{7}$	3.
$\frac{1}{8}$	3.2
&c.	&c.

Steam-Engine.
Mr Watt's Expansive Engine.

"The active mind of its ingenious inventor did not stop here. It had always been matter of regret that one-half of the motion was unaccompanied by any work. It was a very obvious thing to Mr Watt, that as the steam admitted above the piston pressed it down, so steam admitted below the piston would press it up with the same force, provided that a vacuum were made on its upper side. This was easily done, by connecting the lower end of the cylinder with the boiler and the upper end with the condenser."

Hitherto we have considered the condensing steam-engine of Watt in its application to the purpose of working the large pumps used to draw water from mines or to supply reservoirs from a lower level. This, indeed, was the most obvious and immediate application of the steam-engine, which was at first introduced as a substitute for the atmospheric pumping engine of Watt.

The steam-engine of revolution of Mr Watt was an invention subsequent to the mining steam-engine or "water-commanding machine." Previous to the time of Watt, indeed, there had been a few attempts made to produce a revolving motion by means of steam, such as the case where the engines of Savary and Newcomen drew up water, which, falling upon the buckets of a wheel, produced its revolution. There had also been many attempts to apply the atmospheric pumping-engine directly to this purpose—Jonathan Hall, Kean, Fitzgerald, Mr Oxley, John Stewart, and Matthew Wasbrough, had all contrived some means of producing a revolving motion from the reciprocation of the great beam of the pumping-engine; but Watt's engine alone had the power of being rendered an efficient and economical motive power.

We shall take the present opportunity of describing Mr Watt's method of communicating the force of the steam-engine to any machine of the rotatory kind.

"VV, fig. 44, represents the rim and arms of a very large and heavy metalline fly. On its axis is the concentric-toothed wheel U. There is attached to the end of the great beam a strong and stiff rod T, to the lower end of which a toothed wheel W is firmly fixed by two bolts, so that it cannot turn round. This wheel is of the same size and in the same vertical plane with the wheel U; and an iron link or strap (which cannot be seen here, because it is on the other side of the two wheels) connects the centres of the two wheels, so that the one cannot quit the other. The engine being in the position represented in the figure, suppose the fly to be turned once round by any external force in the direction of the darts. It is plain, that since the toothed wheels cannot quit each other, being kept together by the link, the inner half (that is, the half next the cylinder) of the wheel U will work on the outer half of the wheel W, so that at the end of the revolution of the fly the wheel W must have got to the top of the wheel U, and the outer end of the beam must be raised to its highest position. The next revolution of the fly will bring the wheel W and the beam connected with it to their first positions; and thus every two revolu-

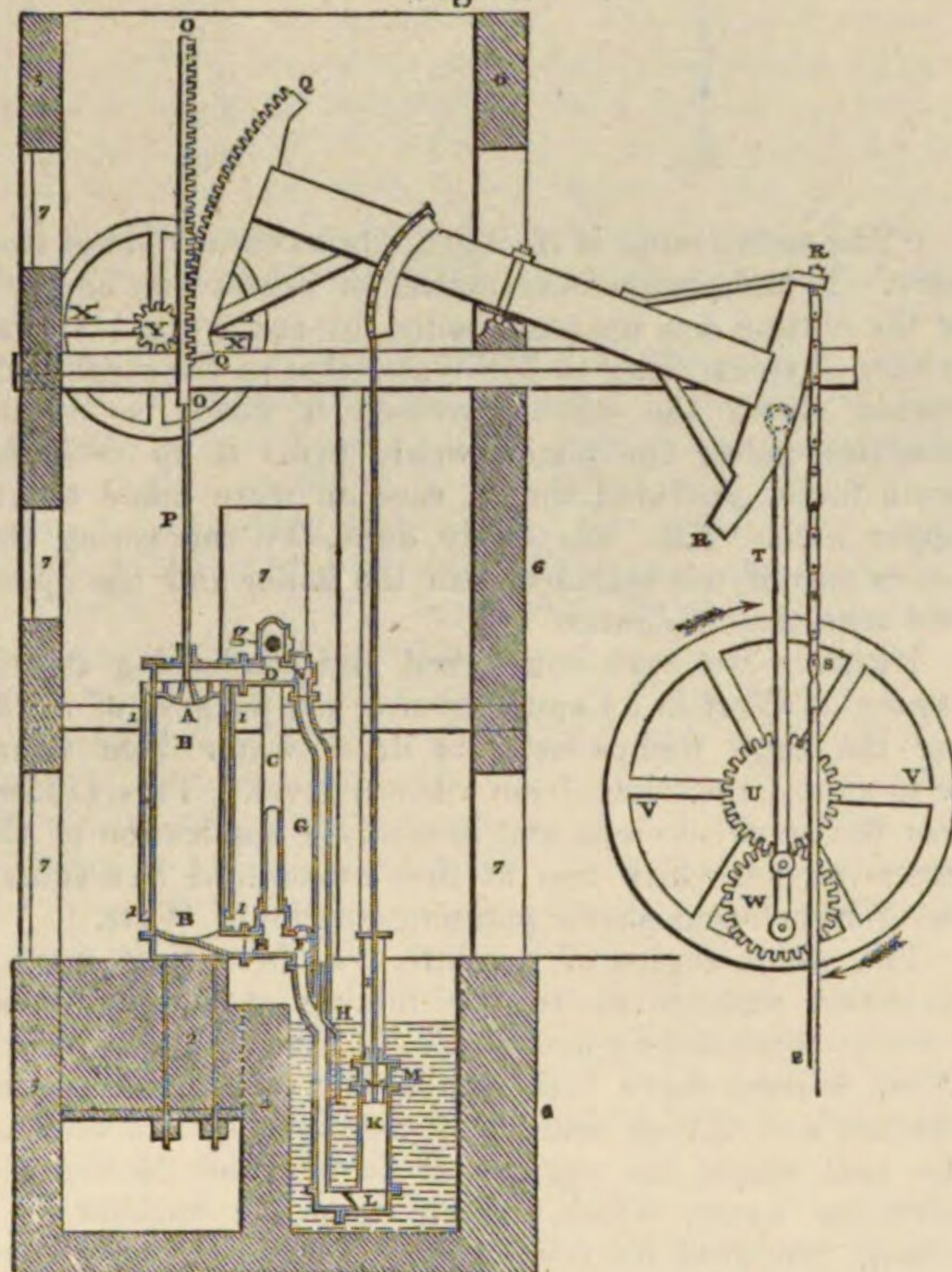
Mr Watt's Engine of Revolution.

Steam-Engine.

Mr Watt's Engine of Revolution.

tions of the fly will make a complete period of the beam's reciprocating movements. Now, instead of supposing the fly to drive the beam, let the beam drive the fly. The

Fig. 44.



motions must be perfectly the same, and the ascent or descent of the piston will produce one revolution of the fly.

“It is proper here to give the history of this invention. I had very early turned my mind to the producing continued motions round an axis, and it will be seen by reference to my first specification in 1769, that I there described a steam-wheel, moved by the force of steam acting in a circular channel against a valve on one side, and against a column of mercury or some other fluid metal on the other side. This was executed upon a scale of about six feet diameter at Soho, and worked repeatedly, but was given up, as several practical objections were found to operate against it. Similar objections lay against other rotative engines which had been contrived by myself and others, as well as to the engines producing rotatory motions by means of ratchet-wheels. Having made my reciprocating engines very regular in their movements, I considered how to produce rotative motions from them in the best manner; and amongst various schemes which were subjected to trial, or which passed through my mind, none appeared so likely to answer the purpose as the application of the crank in the manner of the common turning lathe, (an invention of great merit, of which the humble inventor, and even its era, are unknown.) But, as the rotative motion is produced in that machine by the impulse given to the crank in the descent of the foot only, and behoves to be continued in its ascent by the momentum of the wheel, which acts as a fly, and being unwilling to load my engine with a fly heavy enough to continue the motion during the ascent of the piston, (and even were a counter-weight employed to act during that ascent of a fly heavy enough to equalize the motion,) I proposed to employ two engines acting upon two cranks fixed on the same axis at an angle of one hundred and twenty degrees to one an-

other, and a weight placed upon the circumference of the fly at the same angle to each of the cranks, by which means the motion might be rendered nearly equal, and a very light fly only would be requisite. This had occurred to me very early, but my attention being fully employed in making and erecting engines for raising water, it remained *in petto* until about the year 1778 or 9, when Mr Wasbrough erected one of his ratchet-wheel engines at Birmingham, the frequent breakages and irregularities of which recalled the subject to my mind, and I proceeded to make a model of my method, which answered my expectations; but having neglected to take out a patent, the invention was communicated by a workman employed to make the model to some of the people about Mr Wasbrough's engine, and a patent was taken out by them for the application of the crank to steam-engines. This fact the said workman confessed, and the engineer who directed the works acknowledged it, but said, nevertheless, the same idea had occurred to him prior to his hearing of mine, and that he had even made a model of it before that time, which might be a fact, as the application to a single crank was sufficiently obvious. In these circumstances I thought it better to endeavour to accomplish the same end by other means, than to enter into litigation, and, if successful, by demolishing the patent, to lay the matter open to every body. Accordingly, in 1781, I invented and took out a patent for several methods of producing rotative motions from reciprocating ones, amongst which was the method of the sun and planet wheels described in the text.

“This contrivance was applied to many engines, and possesses the great advantage of giving a double velocity to the fly; but is perhaps more subject to wear, and to be broken under great strains, than the crank, which is now more commonly used, although it requires a fly-wheel of four times the weight, if fixed upon the first axis. My application of the double engine to these rotative machines rendered unnecessary the counter-weight, and produced a more regular motion; so that, in most of our great manufactories, these engines now supply the place of water, wind, and horse mills; and instead of carrying the work to the power, the prime agent is placed wherever it is most convenient to the manufacturer.”

“Let us now trace the operation of this machine through all its steps. Let us suppose that the lower part of the cylinder BB, fig. 44, is exhausted of all elastic fluids; that the upper steam-valve D and the lower eduction valve F are open, and that the lower steam-valve E and upper eduction-valve N are shut. It is evident that the piston must be pressed toward the bottom of the cylinder, and must pull down the end of the working-beam by means of the toothed rack OO and sector QQ, causing the other end of the beam to urge forward the machinery with which it is connected. When the piston arrives at the bottom of the cylinder, the valves D and F are shut by the plug-frame, and E and N are opened. By this last passage the steam gets into the eduction-pipe, where it meets with the injection water, and is rapidly condensed. The steam from the boiler enters at the same time by E, and pressing on the lower side of the piston, forces it upwards, and by means of the toothed rack OO and toothed sector QQ forces up that end of the working-beam, and causes the other end to urge forward the machinery with which it is connected; and in this manner the operation of the engine may be continued for ever.

“The injection water is continually running into the eduction-pipe, because condensation is continually going on, and therefore there is a continual atmospheric pressure to produce a jet. The air which is disengaged from the water, or enters by leaks, is evacuated only during the rise of the piston of the air-pump K.

Steam-Engine.

Mr Watt's Engine of Revolution.

Steam-Engine.
Mr Watt's Engine of Revolution.

"It is evident that this form of the engine, by maintaining an almost constant and uninterrupted impulsion, is much fitter for driving any machinery of continued motion than any of the former engines, which were inactive during half of their motion. It does not, however, seem to have this superiority when employed to draw water; but it is also fitted for this task. Let the engine be loaded with twice as much as would be proper for it if a single stroke engine, and let a fly be connected with it. Then it is plain that the power of the engine during the rise of the steam-piston will be accumulated in the fly; and this, in conjunction with the power of the engine during the descent of the steam-piston, will be equal to the whole load of water.

"The engraving here referred to is copied from the drawing of the double engine in the above patent of 1782, and is that of an experimental engine, no others having ever been made exactly similar. I have now added engravings of one of the Albion mill engines, fig. 45, 46, being one of the earliest double engines erected for sale. I do not exactly recollect the date of the invention of the double engine, but a drawing of it is still in my possession, which was produced in the House of Commons when I was soliciting the act of Parliament for the prolongation of my patent in 1774-5. Having encountered much difficulty in teaching others the construction and use of the single engine, and in overcoming prejudices, I proceeded no farther in it at that time, nor until, finding myself beset with a host of plagiaries and pirates in 1782, I thought it proper to insert it, and some other things, in the patent above-mentioned.

Watt's Description of the Albion Mill Engine.

"Fig. 45 is a vertical and fig. 46 an horizontal section of one of the Albion Mill Engines.

"The steam-pipe F conveys steam from the boiler *n* to the cross-pipe, or upper steam-nozzle G, and by the perpendicular steam-pipe I, to the lower steam-nozzle K. In the nozzle G is a valve, which, when open, admits steam into the cylinder *above* the piston B, (fig. 48,) through the horizontal square pipe at its top; and in the lower steam-nozzle K there is another valve, which, when open, admits steam into the cylinder *below* the piston. In the upper exhaustion-nozzle H is a valve, which, when open, admits steam to pass from the cylinder *above* the piston into the exhaustion-pipe J, which conveys it to the condensing-vessel M, where it meets the jet of the injection from the cock N, and is reduced to water; and, in the lower exhaustion-nozzle L, there is also a valve, which, when open, admits steam to pass out of the cylinder *below* the piston, by the eduction-pipe, into the condenser M.

"The piston being at the top of its stroke, the valves G and L are to be opened, and the fly-wheel *m* turned by hand about one-eighth of a revolution, or more, in the direction in which it is intended to move; the steam which is then in the cylinder will pass by L into the condenser, when, meeting the jet of water from the injection-cock, it will be converted into water, and the cylinder thus becoming exhausted, the steam, entering the cylinder by the valve G, will press upon the piston and cause it to descend, while, by its action upon the working-beam through the piston-rod, &c., it pulls down the cylinder-end of the beam, and raises up the outer-end and the connecting rod *h*, which causes the planet-wheel *i* to tend to revolve round the sun-wheel *j*; but the former of these wheels, being fixed upon the connecting-rod so that it cannot turn upon its own axis, and its teeth being engaged in those of the sun-wheel, the latter, and the fly-wheel, upon whose axle or shaft it is fixed, are made to revolve in the desired direction, and give motion to the mill-work.

VOL. XX.

"As the piston descends, the plug-tree Z also descends, and a clamp, or slider *q*, fixed upon the side of the plug-tree, presses upon the handle *l* of the upper Y-shaft, or

Steam-Engine
Mr Watt's Engine of Revolution.

Fig. 45.

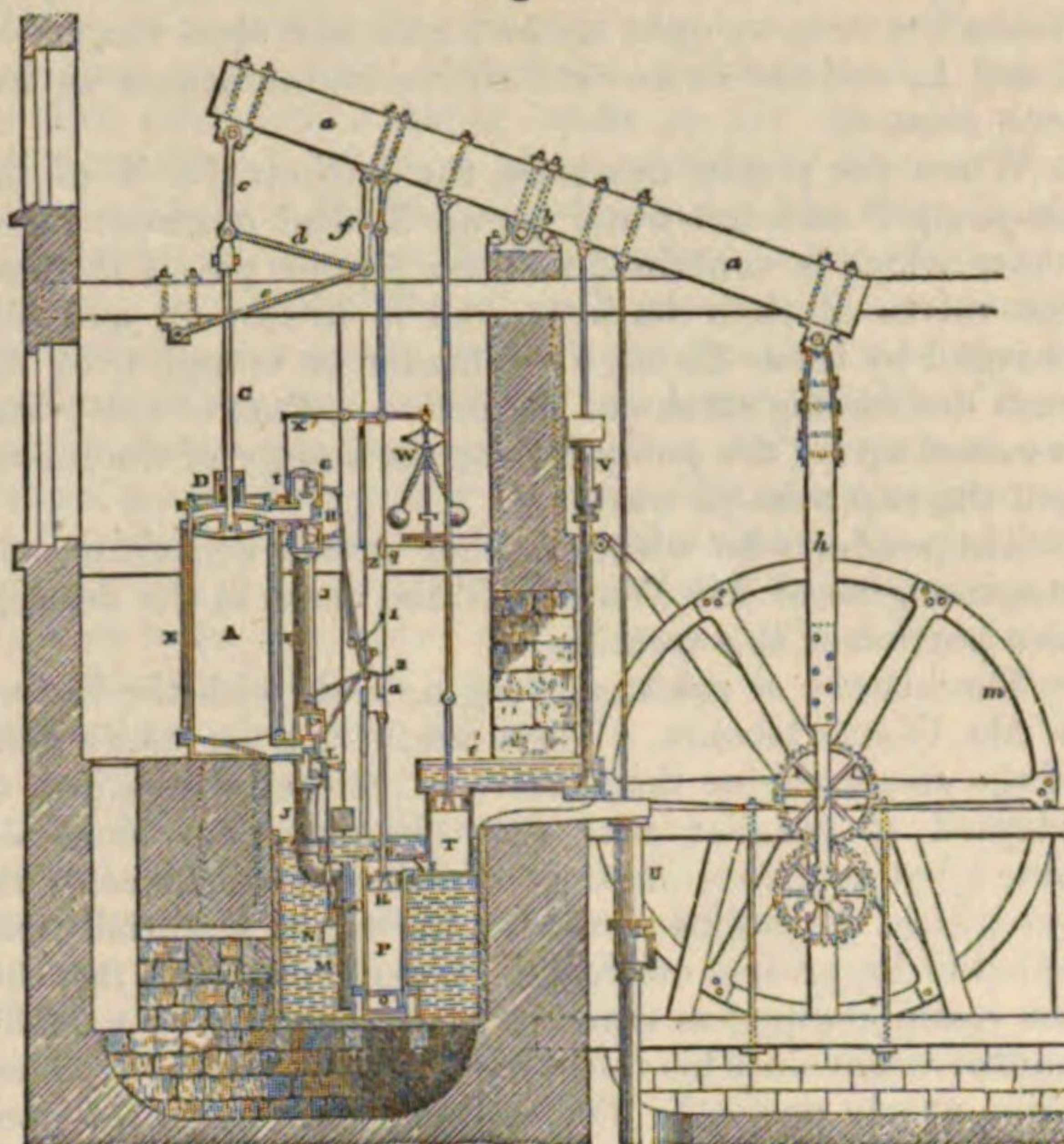
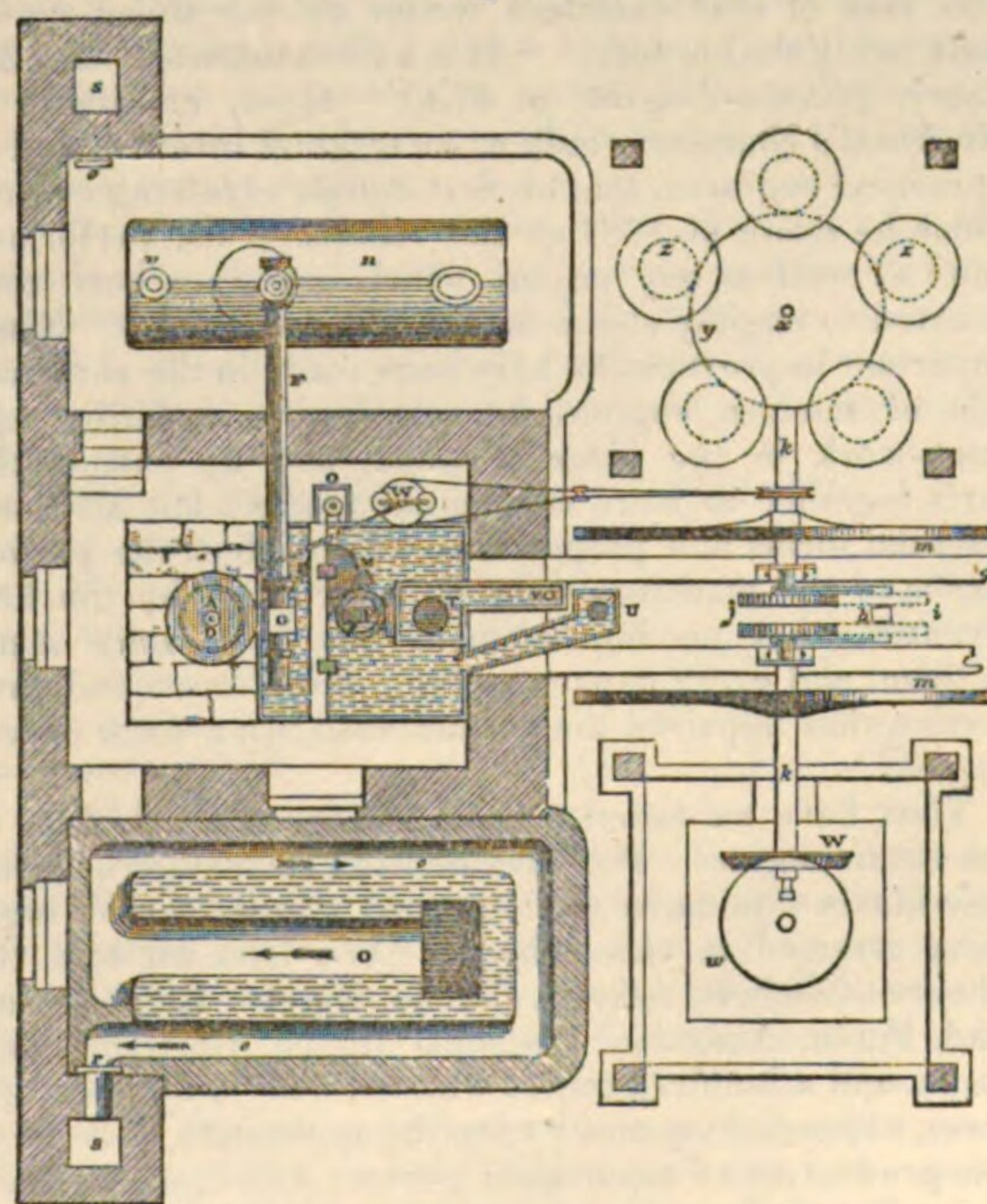


Fig. 46.



axis, and thereby shuts the valves G and L; and the same operation, by disengaging a detent, permits a weight suspended to the arm of the lower Y-shaft to turn the shaft upon its axis, and thereby to open the valves K and H. The moment previous to the opening these valves, the piston had reached the lowest part of its stroke, and the cylinder *above* the piston was filled with steam; but as soon as H is opened, that steam rushes by the eduction-pipe J, into the condenser, and the cylinder *above* the piston becomes exhausted. The steam from the boiler entering by I and K, acts upon the *lower* side of the

4 M

Steam-Engine.
Watt's Engine of Revolution.

piston, and forces it to return to the top of the cylinder. When the piston is very near the upper termination of its stroke, another slider *a* raises the handle 2, and in so doing disengages the catch, which permits the upper Y-shaft to revolve upon its own axis and open the valves G and L, and the downward stroke recommences as has been related.

When the piston descends, the buckets R, T of the air-pump P and hot-water pump T also descend. The water which is contained in these pumps passes through the valves of their buckets, and is drawn up and discharged by them through the lander or trough *t*, by the next descending stroke of the piston. Part of this water is raised up by the pump V, for the supply of the boiler, and the rest runs to waste.

The reader who wishes further details concerning the steam-engine of Mr Watt, will find them in the descriptive portion of this treatise.

Conclusion of the History.

The history of the steam-engine ends with the history of Mr Watt's labours. There are, it is true, many parts of the steam-engine that have been altered, simplified, or adapted to peculiar uses and circumstances since his time; but these are matters of minor importance, without which, the engine would not have been materially curtailed of its present efficiency. It is a remarkable fact that the steam-engine has scarcely received any very valuable improvement since his time. He, in fact, rendered it a machine nearly perfect. The testimony of Mr Farey upon this subject is explicit, and must be conclusive on the subject with every one who has the means of ascertaining the very high estimation to which the knowledge and practical skill of that excellent writer on the steam-engine most justly entitle him. "It is a circumstance," says Mr Farey, (*Steam-Engine*, p. 473,) "highly creditable to Mr Watt's character, both as an original inventor and as a practical engineer, that his first double-revolving engine, which he made in 1787 at the Albion Mills, performed quite as well as any engine which has since been constructed to employ steam on the same principles. Some important improvements have been made in the construction of modern engines by substituting cast-iron and stone-work in the place of wood, and by putting the parts together in more substantial modes; but all those essential forms and proportions which affect the performance of the machine, were so ascertained by the first inventor, that no improvement has been since made in them, and every departure from those forms and proportions has impaired the performance in a greater or less degree."

Thus have we taken a rapid survey of the history of the steam-engine. We have omitted the names of many individuals who have distinguished themselves by ingenuity directed to this subject. We have omitted the labours of Gebert, Alberti, Cardan, Decaus, Branca, Morland, Papin, Amonton, Leupold, Meyer, Bosfrand, Gessanne, and a hundred others who have, all in different degrees, expended ingenuity upon the application of steam to the production of mechanical power; and these we have omitted not because we consider their labours either undeserving of notice or uninteresting to the general reader, but because they have not contributed towards the production of the modern steam-engine, and because an account of their works would rather serve to illustrate the possible varieties of the machine and the fertility of the human mind in mechanical devices, than either to conduct the reader along the stream of historical succession, or render him better acquainted with the nature and mechanical peculiarities of the steam-engine itself.

Part II.—DESCRIPTION OF THE MODERN STEAM-ENGINE.

Steam-Engine.

Of modern steam-engines there are two distinct species—the high-pressure and low-pressure engines. The former is simple, light, and of few parts, generally used for locomotive engines, steam-carriages, steam-vessels of a light and rapid construction, and such other purposes as require portability or cheapness. The latter is more complex, but more effective; more expensive in original construction, but more durable and more economical in consumption of fuel. The first is more commonly in use in America, the latter in this country. The high-pressure engine is sometimes also called the non-condensing steam-engine, to distinguish it from the low-pressure engine, which is also called the condensing steam-engine; but there is sometimes a combination effected of some of the parts and principles of both these species, in what is called a high-pressure condensing engine, by which, for certain purposes, the peculiar merits of both species are combined in the same machine.

Of these two sorts of steam-engine it is remarkable that the more elementary and simple—that which is the more easily conceived and understood—was not invented and brought into practical use until long after the other kind had been very extensively used and made known by its inventor, James Watt. It appears to us, that we are to consider Oliver Evans of Philadelphia as the inventor of the modern high-pressure engine. Before 1786 he had contrived and made experiments upon a high-pressure engine, which seems to have been in all essential respects similar to our own. Indeed, it appears that the Americans have taken the form and arrangements of their engines from Evans, as implicitly as in this country we have adopted those of Watt. The history of Evans consists almost entirely of the romance of real life. Sanguine and energetic, he continually encountered difficulties only to overcome them, and to encounter renewed disaster and disappointment, till he at length died of a broken heart. To him we attribute the rapid advancement of America, at the commencement of the present century, in all that relates to the introduction of the steam-engine in its multifarious applications, and especially in steam navigation. He had awakened in that nation a lively sense of the advantages which they were likely to derive from the introduction of the power of steam, and placed in their hands an instrument well fitted for their use, and which they were not slow to adopt and apply.

The high-pressure or non-condensing engine consists of two principal members, *generator* or *boiler* and *working cylinder*, each with sundry appendages. The low-pressure or condensing steam-engine consists of three principal members, *generator*, *cylinder*, and *refrigerator* or *condenser*, each with sundry appendages.

The generator and working cylinder, with their appendages, are nearly the same in both kinds of steam-engine, the presence of a condenser or refrigerator forming the principal and almost only distinction of the second species. By this second species the steam is returned into its first state of water, thereby effecting a saving of heat and of mechanical power; whereas, in the first form of engine, the steam, after performing a certain portion of its labour, is discharged into the open air as useless; a process which can only be advisable in circumstances where the labour and apparatus for condensing would cost more money, and cause more inconvenience than would countervail the loss of fuel and heat and power.

As, therefore, the high-pressure non-condensing steam-engine is simpler in its action and construction than the low-pressure condensing engine, it is convenient to con-

The Modern Steam-Engine. Two Species.

Steam-Engine.

sider, in the first instance, its mechanism and management, and afterwards, how far it may require to be modified in order to acquire the advantage of condensation.

The High-Pressure Non-Condensing Steam-Engine.

The elastic force of steam is a phenomenon with which we become acquainted very early in life. We see that when water boils furiously in a kettle or caldron which is closely fitted by a lid or cover, it has a tendency to raise it up or drive it off with considerable force; and that the steam, collecting in the upper part of the vessel, rushes with considerable velocity out of any crevice or pipe which communicates with the open air.

The force of the steam which is thus issuing from the spout of a kettle or crevice in the cover of a caldron is comparatively slight; and the steam which thus rises from boiling water is called low-pressure steam. But if we stop up the spout and close the cover with accuracy, so as to confine the steam within the kettle or boiler, the water will become hotter and hotter, and the steam stronger and stronger, until it will either force up the cover with violence, or altogether burst asunder the sides of the boiler. In this confined and heated state the steam acquires, from its properties, the descriptive appellation of high-pressure steam.

Pressure of Steam.

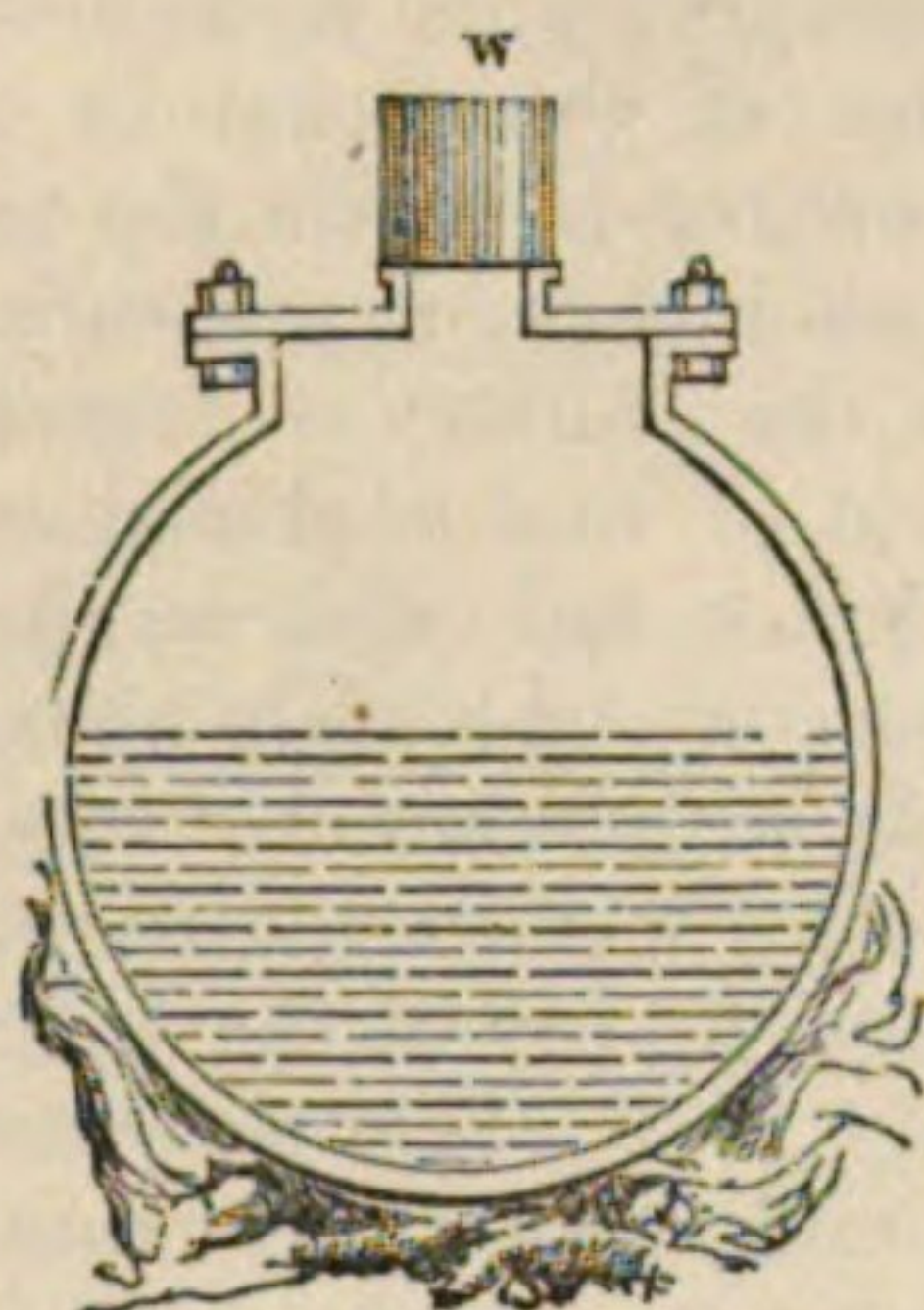
Engineers are in the habit of reckoning the force of high-pressure steam by a very simple expedient. They place a weight such as *W* (Fig. 47,) upon a hole on the top of the boiler. This hole being square, and an inch in length and breadth, and the weight being equal to one pound, when the steam is strong enough just to blow the weight off the hole, they call that *steam of an elastic force equal to one pound on the square inch*. They then place a weight of two pounds upon this hole of a square inch, and continue the heat until the steam just blows it off, and that is called *steam of the pressure of two pounds on the square inch*. And, in like manner, when steam is confined and heated until it acquire force enough to blow weights of three, four, five, fifteen, or fifty pounds off an aperture of not more than a square inch in extent, that is technically called *steam of the elastic pressure of three, four, five, fifteen, and fifty pounds on the square inch*. It is difficult to say whether there be any limit to the elastic force which steam may acquire from continued heat and confinement: it is known to be even as powerfully elastic as gunpowder, and pressures of one thousand pounds an inch have been produced.

The pressures generally adopted for high-pressure engines are from fifteen to one hundred and twenty pounds on the inch. Of course, when there is a given pressure on any one inch of the surface of a boiler, there will be the same on every other inch of surface; and if the aperture under the weight be any number of times greater than one inch, it will just require so much the more weight to keep it closed. The standard by which the pressure is reckoned and calculated is, however, always the square whose side is one inch.

Safety-valve.

By placing a movable weight upon an aperture of given size in this manner, the engineer not only ascertains the amount of the elastic force of the steam tending to burst the boiler, but he also constructs a *safety-valve* by which to avert the danger of an explosion of the boiler.

Fig. 47.

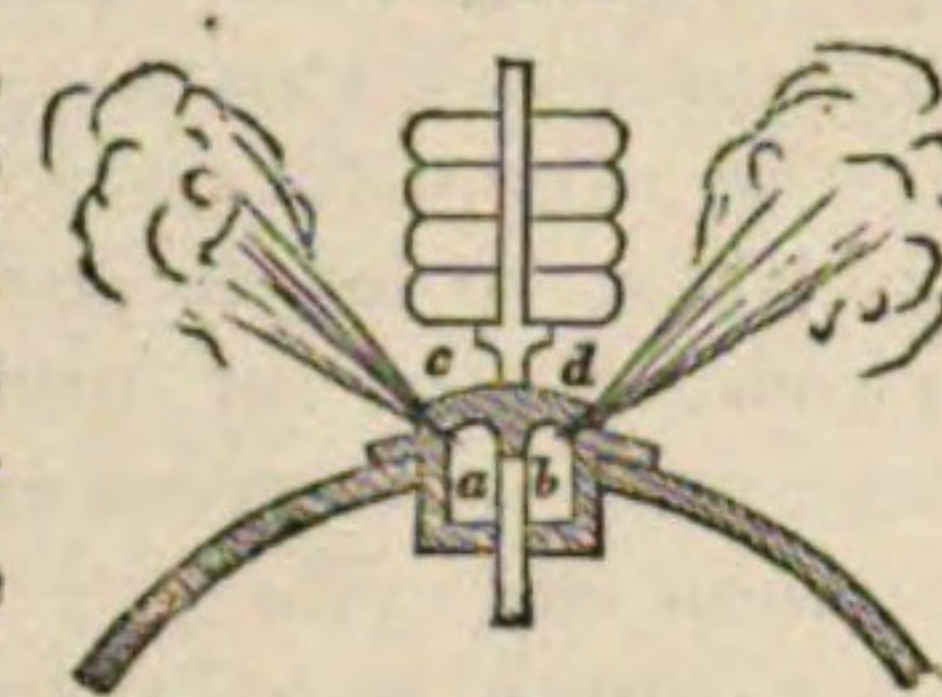


Dr Desaguliers relates a circumstance which happened very early in the history of the steam-engine, when, for want of proper precautions of this nature, "the steam burst the boiler with a great explosion, and killed the poor man who stood near, with the pieces that flew asunder, there being otherwise no danger, by reason of the safety-valve being made to lift up and open upon occasion." Now, a given weight of lead or iron laid on a hole in the top of a boiler so as to close it, is a sufficient and common form of safety valve; for whenever the pressure of the steam becomes sufficient to raise the weight, it escapes through the opening into the air without doing any mischief. A large weight of lead, simply placed on the opening, is a very common and simple mode of providing for the safety of the apparatus.

Steam-Engine. Safety-valve.

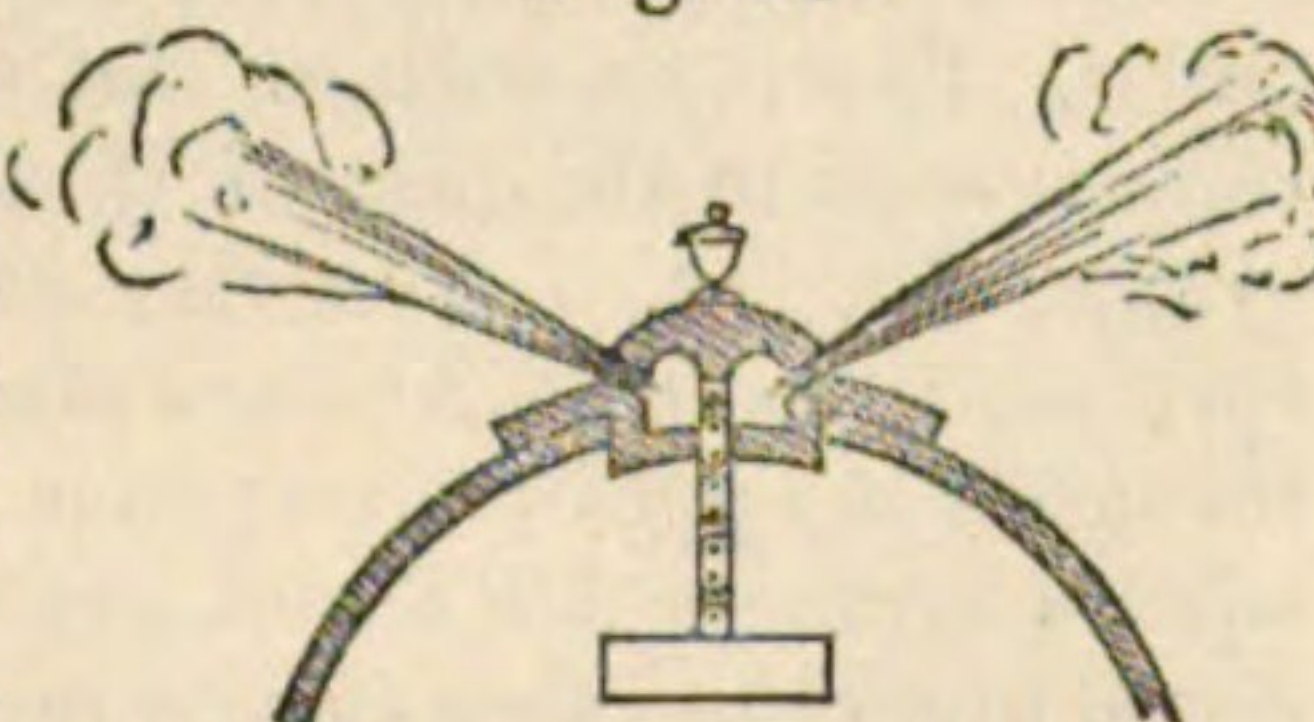
But this plan becomes inconvenient when the pressure is high and the weight great, because it then becomes so high as to be unsteady; and, in order to remedy the inconvenience, what is called a *valve* is used, separate from, and in addition to, the weight, as shown in the accompanying diagram, fig. 48. A valve-seat *a b*, formed of cast brass, is fixed in the aperture, and is accurately fitted by the valve itself *c d*, the edges of which, at *c* and *d*, are carefully turned and tapered, so as to fit the neck of *a b*, and ground in its place with emery powder, which makes it perfectly steam-tight. A spindle protrudes downwards from the valve through a guide which keeps it in a straight line, and prevents it from falling on one side of the valve after having been raised. This same spindle, rising upwards, carries upon a crossbar a series of large cylindrical weights which may be increased or diminished in number as the case may require.

Fig. 48.



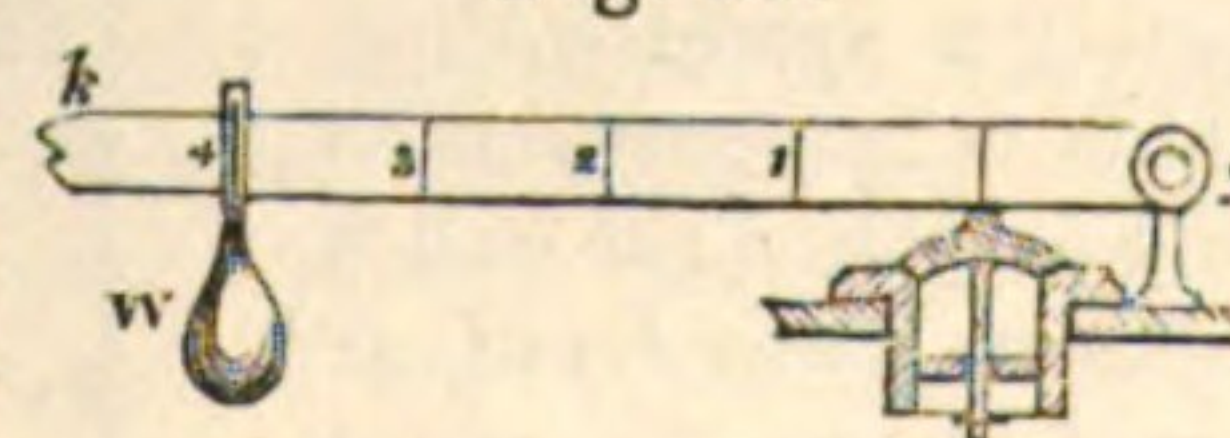
It is a practical fault of this valve that the tall erect spindle may easily become bent or injured by accident, and also that the weight upon it may too easily be handled, so as wantonly to be increased; hence, a safety valve, with an internal weight, has been contrived in the following shape. A conical valve is placed in its seat in every respect as formerly, only the spindle does not rise up but hangs down among the steam, terminating in a chain and weight.

Fig. 49.



In all of these modifications the weight on the safety-valve becomes large and cumbrous when the pressure is high; and a contrivance was devised very early in the history of steam to obviate the inconvenience of this plan, under the name of the lever safety-valve. Instead of placing a great series of weights on the valve itself, a single weight is hung on the end of the longer arm of a lever so as to produce an effect proportional to its distance, and this lever being graduated, shows the amount of the effect which is thus produced. In the figure, the valve, valve-rod, and spindle are all arranged as formerly: but a lever *g k* rests on the top of a small hemispherical button on the valve; and the one end *g* being a fulcrum, the weight *W* is suspended by a ring from any point of the lever. When, at the point 4, as in the figure, its effect on the valve is four times as great as if directly upon it. The effect of the lever's own weight will, in this case, be

Fig. 50.



Steam-Engine.
Safety-valve.

also equivalent to a certain number of pounds on the valve, which, being properly estimated, the lever safety-valve may be used to indicate with accuracy the pressure of the steam.

Another form of valve has been proposed, as indicating still more correctly the point at which the pressure of the steam is equal to the pressure on the valve. It is a cylinder or flat valve, acted on by a lever and weight; and there are weights on opposite sides of the lever, which has also equal arms. These weights rest on light rollers so as to run down from their places and release the steam entirely, whenever its pressure reaches the prescribed limit. This is the valve of the French Academy and Franklin Institute.

Another form of valve, also cylindrical, was used by Mr Southern for his delicate experiments on high-pressure steam. (See Art. STEAM.) The cylinder of the valve-seat used in the former figures is prolonged upwards, so as to form a vertical cylinder or tube, in which a plug of metal is exactly fitted. This plug is ground with great care, so as to move freely but steam-tight in the cylinder; and a rod from the cylinder passes up through a hole in the top, and is kept down by a lever and weight. A hole in the cylinder allows the steam to escape whenever the pressure on the valve upwards exceeds the pressure of the lever and weights in the opposite direction. The indications of this instrument are found to be very precise.

Another species of safety-valve has of late years come into use, called the spring-valve. It is of two kinds, with a lever and without it. The form without the lever is represented in the first of these diagrams, fig. 54. A series of bent springs, *sp sp sp sp*, &c., are placed alternately in opposite directions, in the square frame *g h k l*, and are forced down upon the valve at *n* by means of a cross-bar *k h* acting at *m*—a small screw at *m* adjusting the pressure by compressing or releasing the spring.

The other form of spring safety-valve interposes a lever between the safety-valve and the spring. *ST*, fig. 55, is what is commonly called a Salter's spring balance, the box *xy*, containing a spiral-spring, which is compressed in the box, when the end *S* is drawn away from, or raised above the point *S*. The finger-screw *S*, adjusts the degree of tension on the end of the lever. The two last species of safety-valve are used in locomotive steam-engines.

Fig. 51.

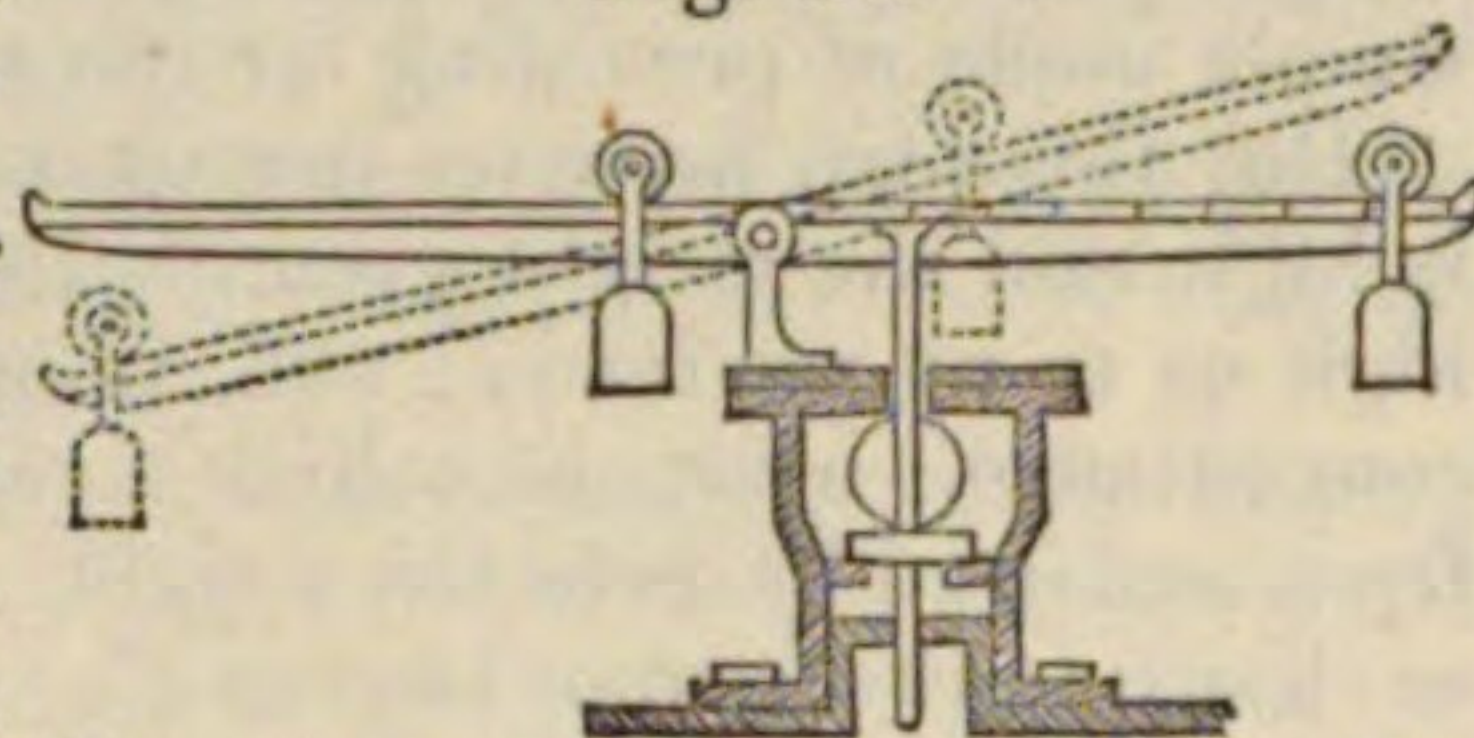


Fig. 52.

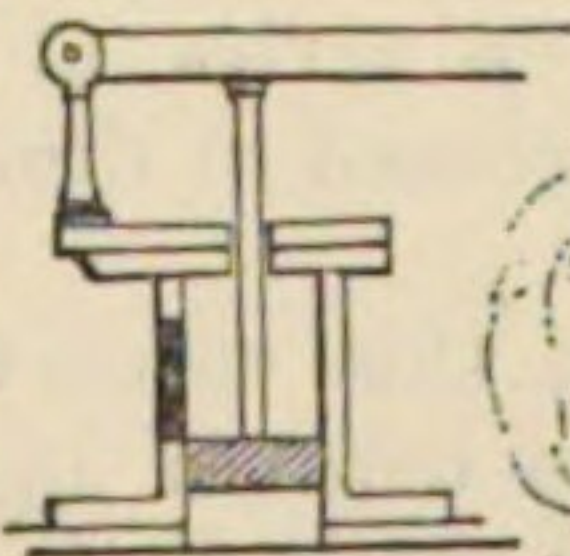


Fig. 53.

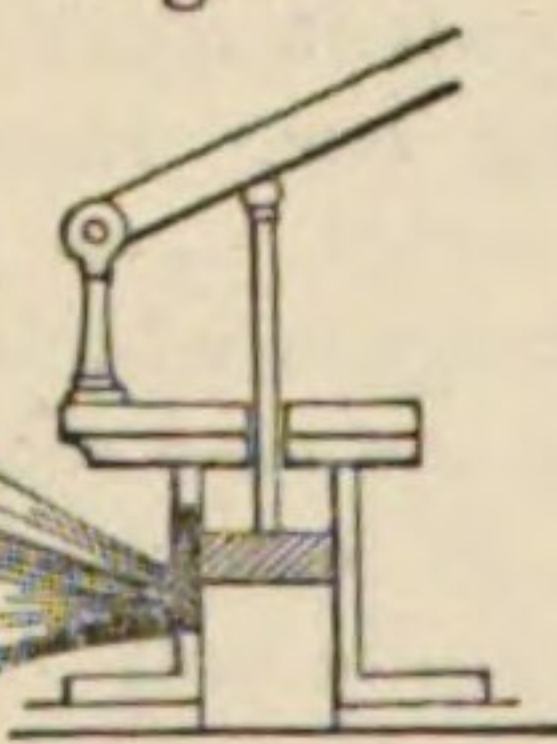


Fig. 54.

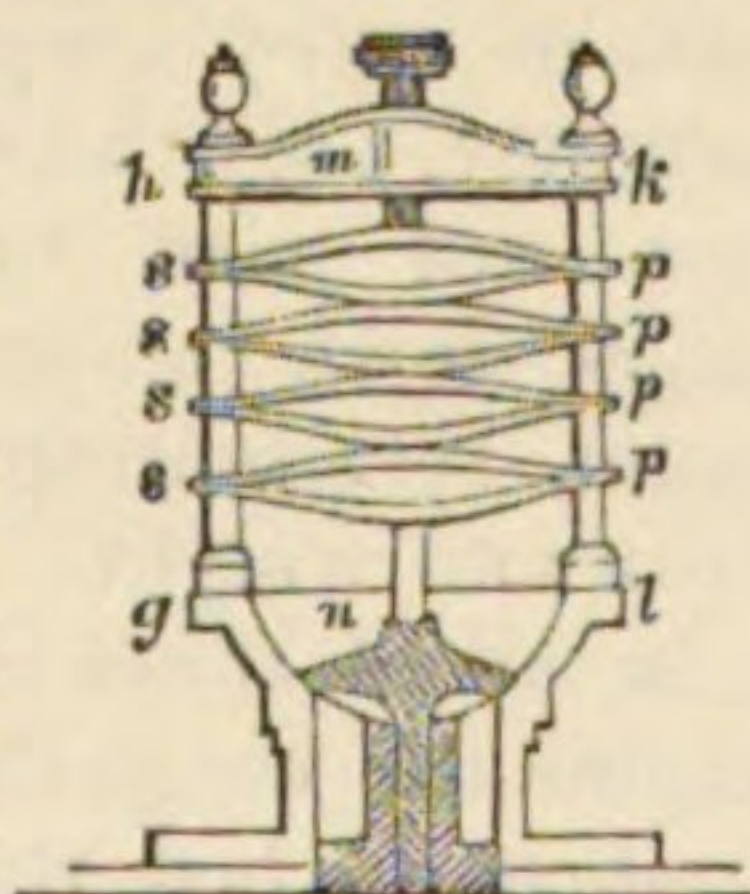


Fig. 55.

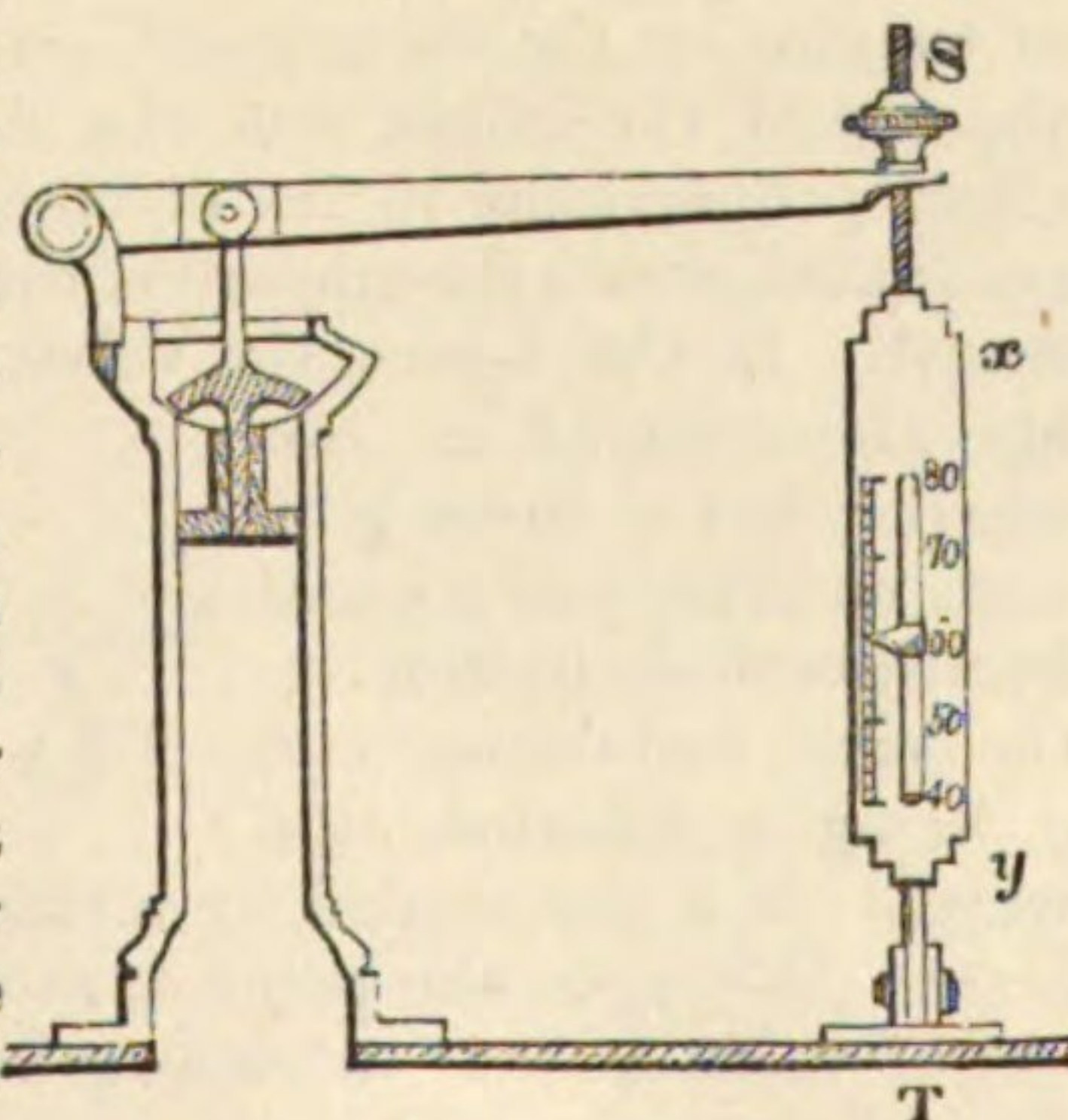


Fig. 56.

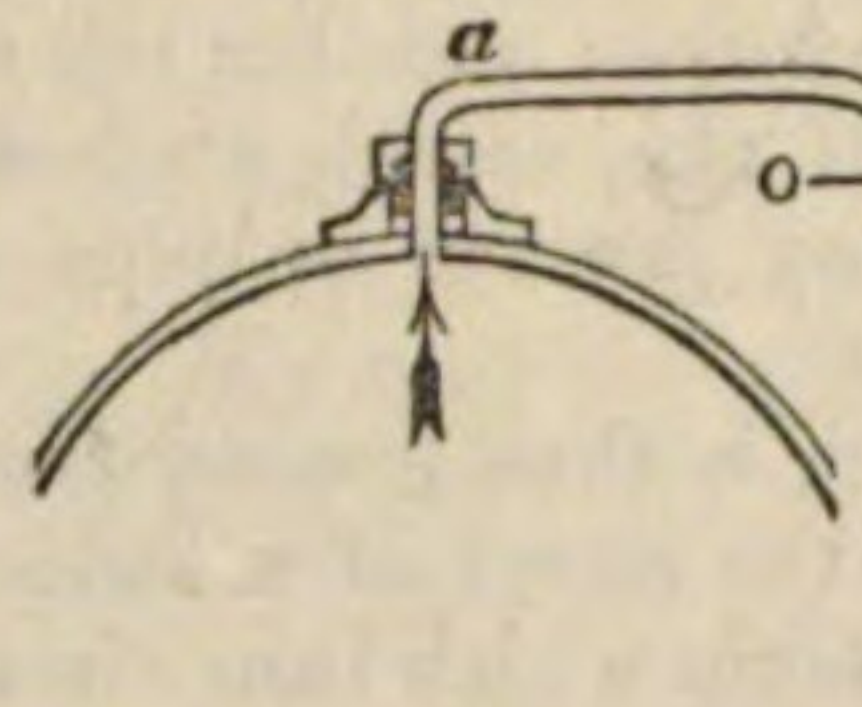
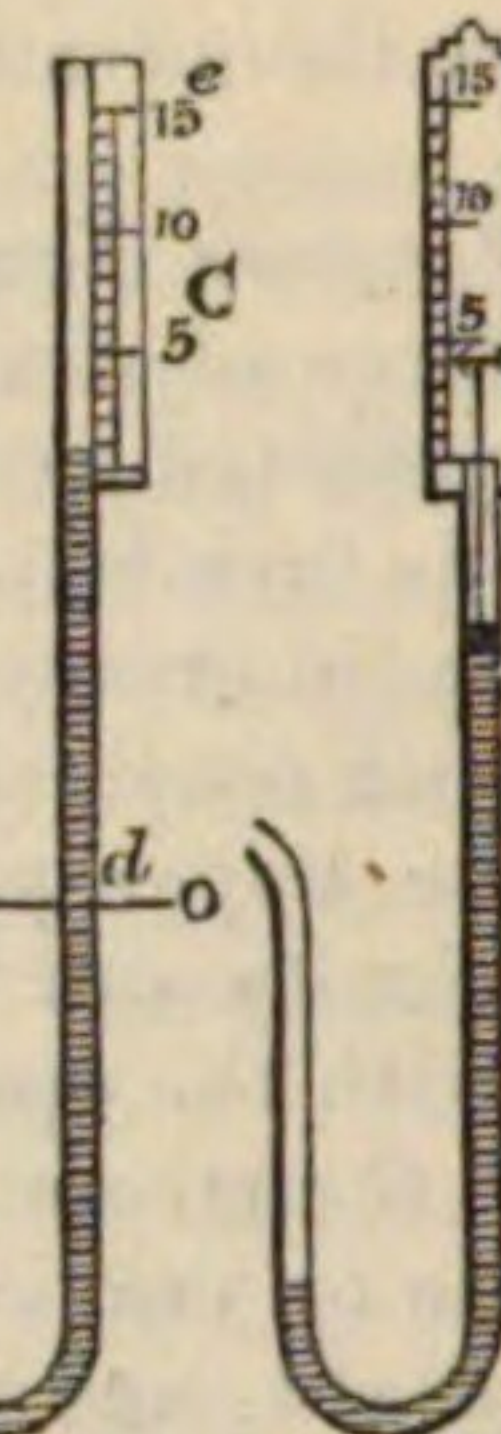


Fig. 57.



Steam-Engine.
Elastic force of Steam.

A totally different method of indicating the pressure of steam in a boiler, is by means of what is called a *mercurial gauge*, communicating with the boiler. Mercury is poured into a bent tube, one end of which springs from the boiler, and the other end is exposed to the air, so that the steam by its pressure raises the mercury in the straight limb of the tube to a height above the level proportioned to that pressure. In the figure *a c d e*, is the bent tube, communicating with the boiler at *a*, and open at the end *e*, the steam presses on the end *c* of the mercury, and raises the other extremity of the fluid to the height *C*. From calculating the weight of mercury, it is reckoned, that for every pound of pressure of the steam in the boiler, there is an inch of mercury raised in the tube; so that, if the space *d c* be nine inches, a pressure of nine lbs. on the square inch in the boiler is indicated. Sometimes also a small float of iron is placed on the mercury, which, carrying a slender rod with an index, points the elevation of the mercury on a scale above the gauge. It is evident that this instrument also acts as a safety-valve, inasmuch as the steam, when too strong, must force the mercury entirely over the top of the tube, and make its escape. A double pipe, on a larger scale, with water in it instead of mercury, would answer the same purpose equally well; only the water would rise one foot and an inch for every pound of pressure of steam in the leg of the double tube, and twice that quantity if the tube were single; which would give a scale of $16\frac{1}{2}$ feet in a double tube, or 33 feet in a single tube, as the column of water raised above the level by a pressure of 15 lbs. on the square inch.

It is convenient to reckon the pressure of steam in larger numbers than pounds, and the quantity that has been fixed is a weight of 15 lbs., or a stone weight, per square inch; and to this weight the name of an atmosphere of pressure has been given, simply because the common atmosphere of air presses on all bodies with a weight of 15 lbs. on the square inch, (see Art. PNEUMATICS.) Thus steam having a pressure of 15 lbs. on the square inch, is called high-pressure steam of the elastic force or strength of one atmosphere. High-pressure steam having a pressure of 30 lbs., is said to have an elastic force of two atmospheres, 45 lbs. of three atmospheres, &c. Sometimes, however, a nomenclature rather different is adopted, and the common steam of boiling water, which exerts no further pressure than merely to balance the atmosphere, is called steam of one atmosphere; and in this case the elastic steam which has been called one atmosphere would be considered as two atmospheres. This nomenclature will be rendered evident by the consideration of the following table:—

High-Pressure Steam of		
0 lbs. on the square inch	is called 0 atmos.	or 1 atmos.
15.....	1.....	2
30.....	2.....	3

Steam-Engine.	45 lbs. on the square inch is called 3 atmos. or 4 atmos.	
60.....	4.....	5
75.....	5.....	6
90.....	6.....	7
105.....	7.....	8
Nomenclature of Pressure.	&c.	&c.

Owing to this degree of ambiguity in these technical measures of pressure, it is always necessary to observe and to specify whether the pressure spoken of is pressure total, or excess above the atmosphere of air. If, for example, four atmospheres be specified, it must be considered whether four atmospheres above the pressure of the atmosphere be meant, as in the first column of the table, or four atmospheres including the atmospheric air pressure, in which case the number in the second column is meant; for, in the former case, high-pressure steam of 60 lbs. on the square inch is meant, and in the latter high-pressure steam of only 45 lbs. above the atmosphere.

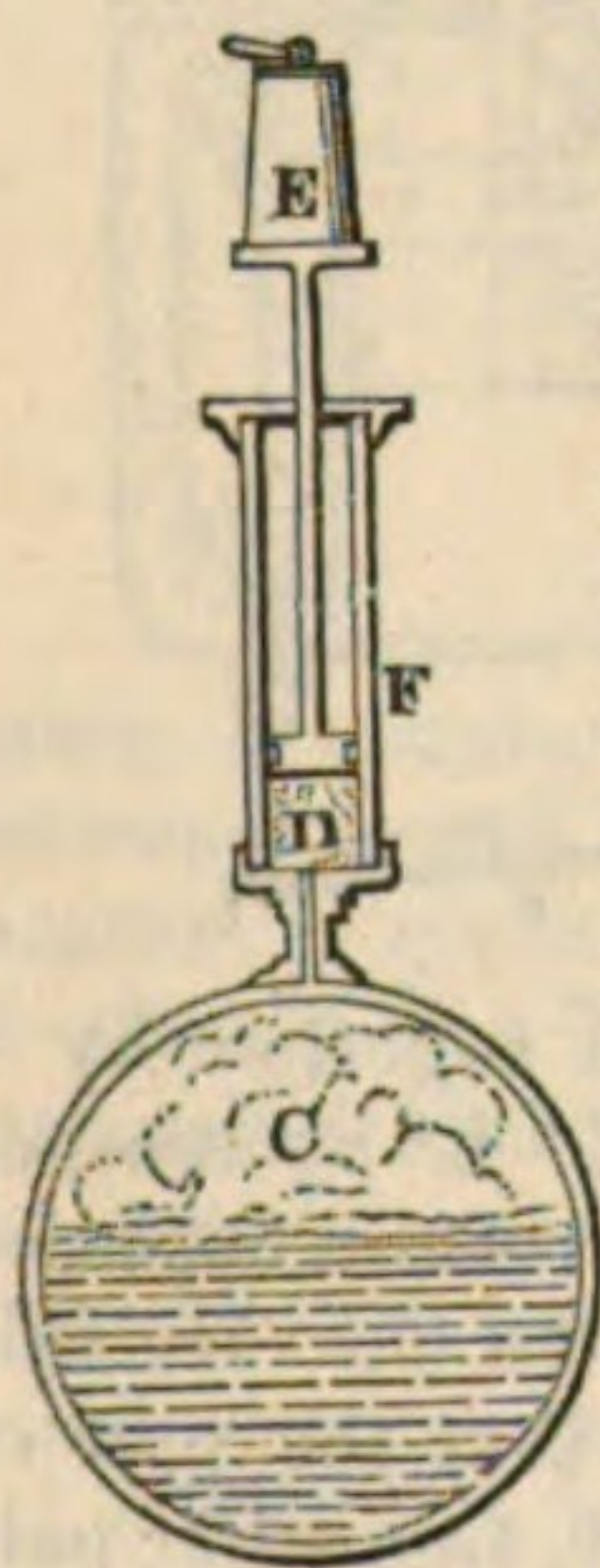
Such are some of the various methods by which the elastic force of high-pressure steam in a boiler may be estimated and shown. We have next to consider the manner in which that force may be applied to the useful purpose of forming a high-pressure steam-engine.

We have already seen how the force of steam, confined in a close boiler and heated until it acquires great elastic force or high pressure, acts upon every point of the surface in which it is enclosed, tending to press it asunder; and how, by sufficiently confining and heating it, weights of five, fifteen, or fifty pounds, resting on only a single square inch of surface, may be supported and upraised. To apply this force to the raising of great weights, is the object of the high-pressure steam-engine; and it has been calculated that 6 lbs. of coal, applied in heating 6 gallons of water into steam, has sufficient force to perform the most arduous labour of a man, for a whole day.

Leupold's High Pressure apparatus, 1725.

One of the simplest and earliest applications of the force of high-pressure steam to raising weights, is given by Jacob Leupold, in his *Theatrum Machinarum Hydraulicarum*, Leipzig, 1725. This we have copied from his work

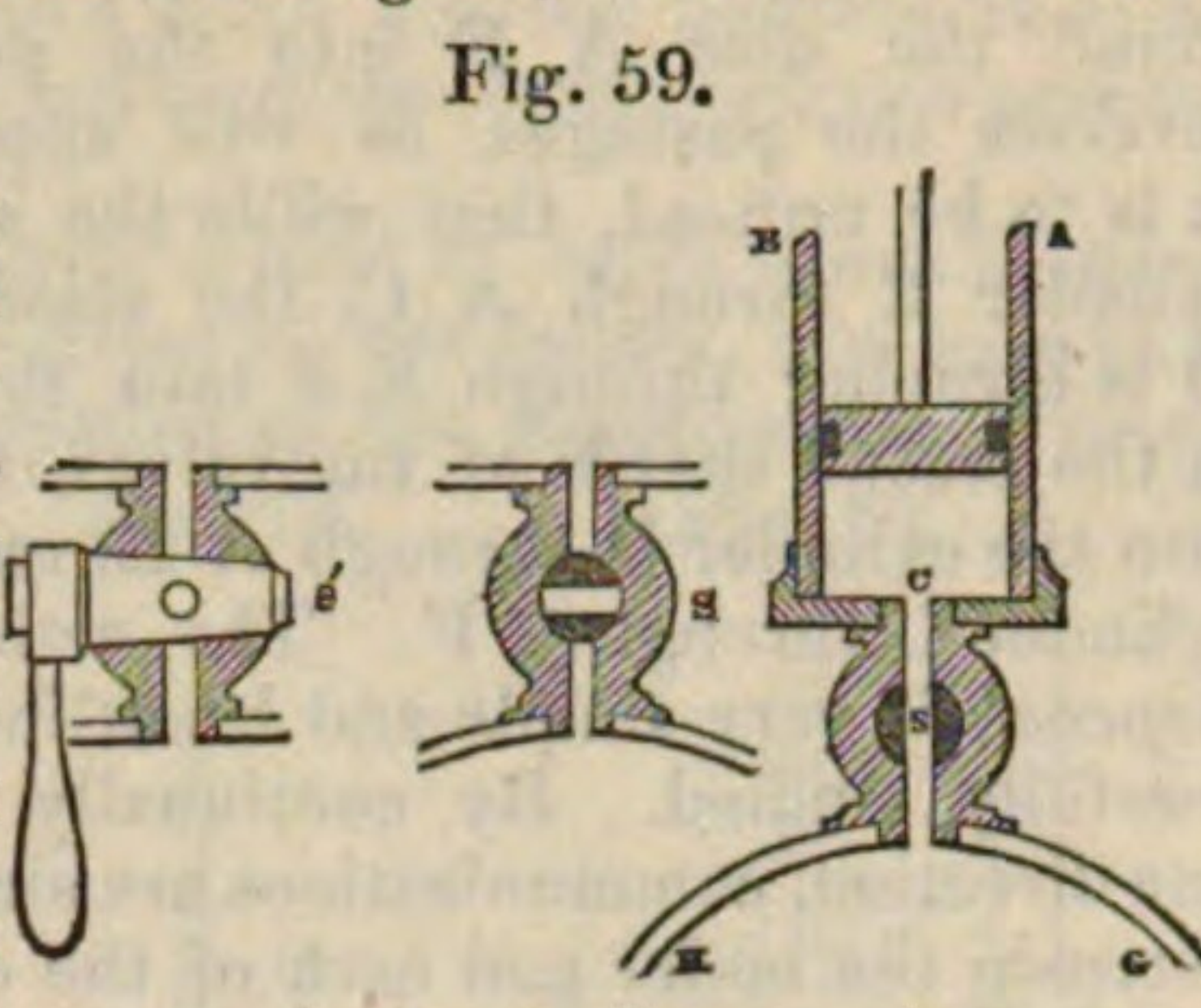
Fig. 58.



in the accompanying figures. We have already seen that the boiler C, fig. 58, being placed on a fire, the elastic force of the steam will raise a weight resting on an aperture. Now, if we conduct the steam in a pipe into any other vessel, such as the cylindrical tube F, in which there is a piston or movable plug D, on the top of which rests the weight E, by a metallic rod E B, connected with the piston, and passing freely through a hole in the top of the cylinder, it is manifest that when the steam becomes strong enough to overcome the pressure of the weight, it will raise up the piston to any required height. If the weight be 15 lbs., and the size of the surface of the piston one square inch, and if the pressure of the steam be equal to any thing more than one atmosphere of elastic force, it will overcome the weight and raise it. If the surface of the piston were double the size, or two square inches in extent, then each inch would be acted on by a force of 15 lbs., and the same elastic force acting on two inches would raise double the weight, or 30 lbs., and so on for any number of square inches; so that, if the piston were a circle of four inches in diameter, which would have a surface of about 12 square inches, on each and all of which a pressure of 15 lbs. was sustained, there might be a total weight of 12 times 15 lbs., or 180 lbs., sustained and raised to the top of the cylinder. The boiler being removed from the fire and allowed to cool down again, the piston might again descend, and this operation be repeated as often as necessary.

But a more convenient form of this apparatus is that which Leupold gives in the next figure,—in which it is unnecessary to remove

the fire. The boiler G H, fig. 59, having a constant fire placed under it, the communication with the cylinder A B C takes place through a passage capable of regulation by a stopcock S, which is shown at S as shut by turning



the handle T. This stopcock is similar to that commonly used for regulating the flow of liquors in vessels of any kind; a small conical plug S' stops up the passage entirely, but being perforated in one direction, allows the communication to take place whenever that perforation is turned round into such a position as to form a continuation of the channel. By this means it is provided that this stopcock shall remain in the position, S' being closed, until the steam has collected in the boiler a sufficient elastic force, after which it is allowed to pass up into the cylinder, by turning the stopcock into the position S when the steam entering the cylinder pushes up the piston and the piston-rod by which the great weight E is raised as before. The piston will then be allowed to descend to the bottom, by allowing the cylinder gradually to cool, when the weight may again be raised as at first; and so on for any number of operations.

But the most perfect of Leupold's machines is that represented in the following figures, 60, 61. It is a true water-pumping high-pressure steam-engine; a machine which

Fig. 60.

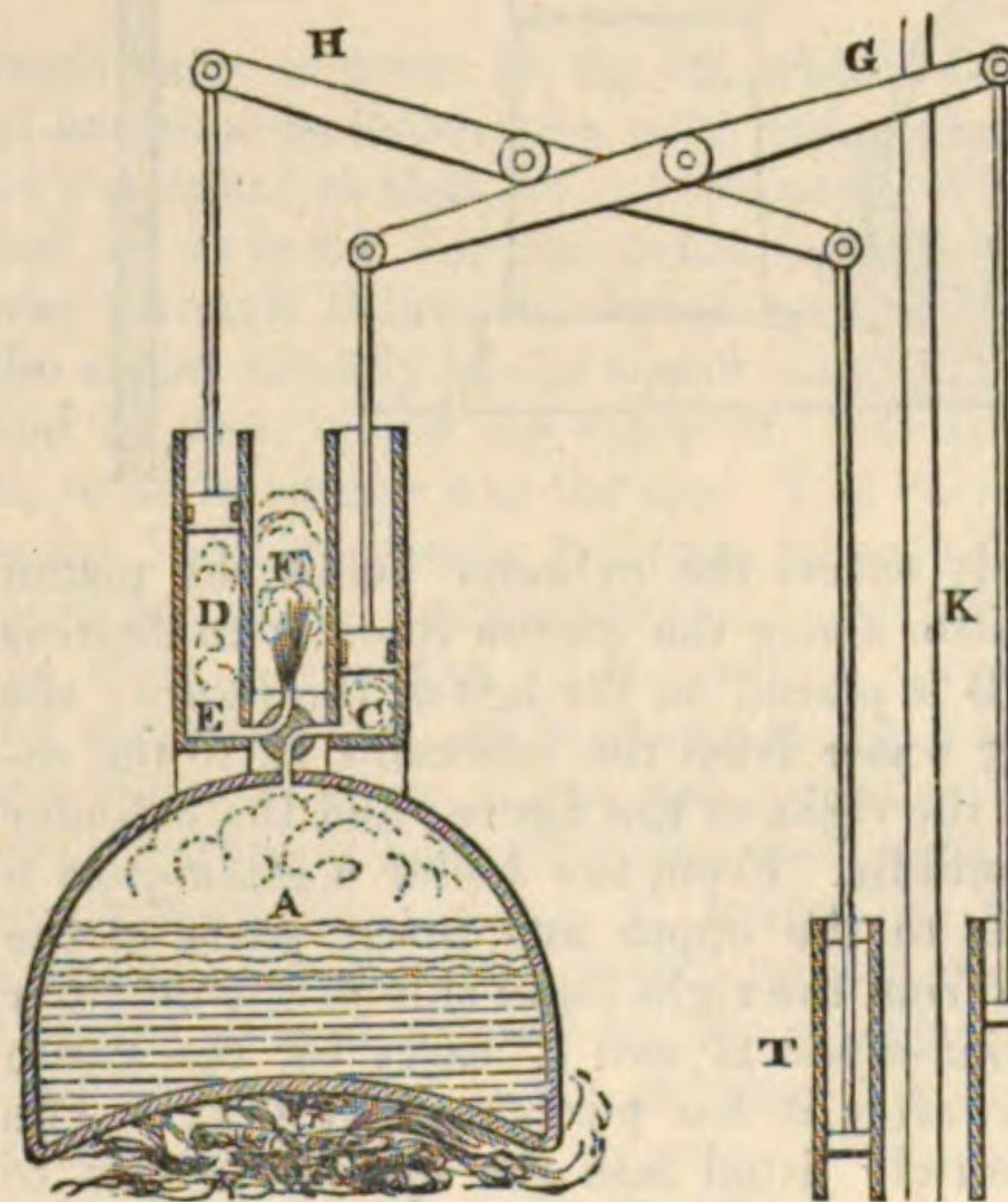
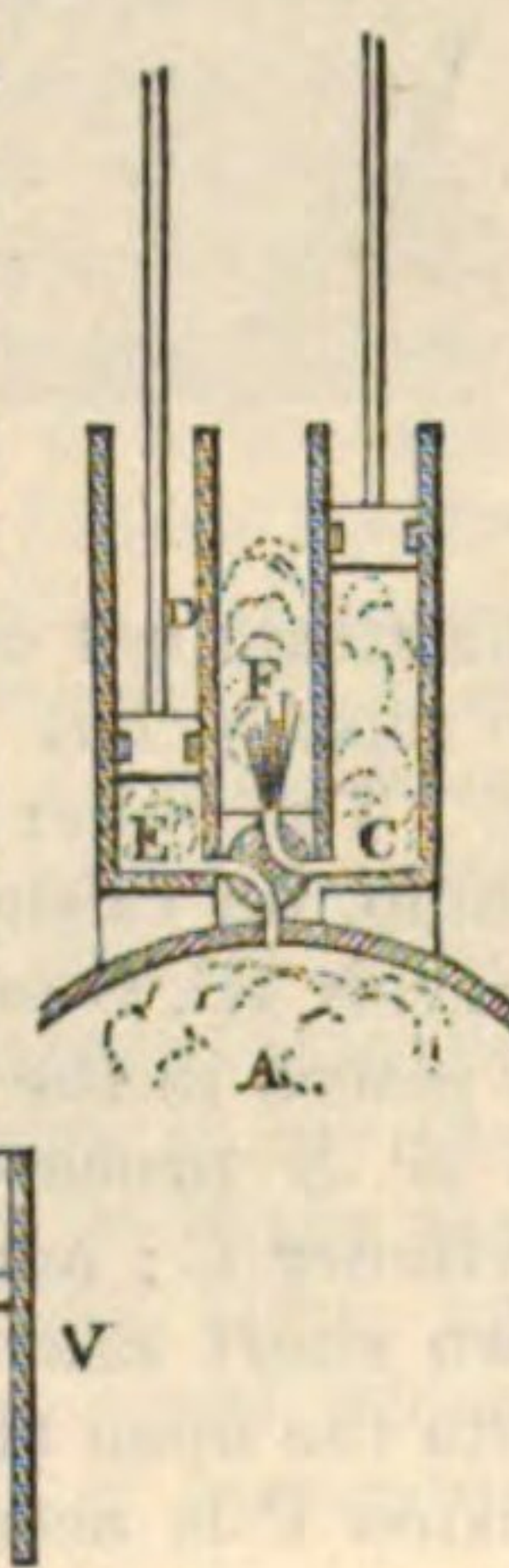


Fig. 61.



Leupold's Engine.

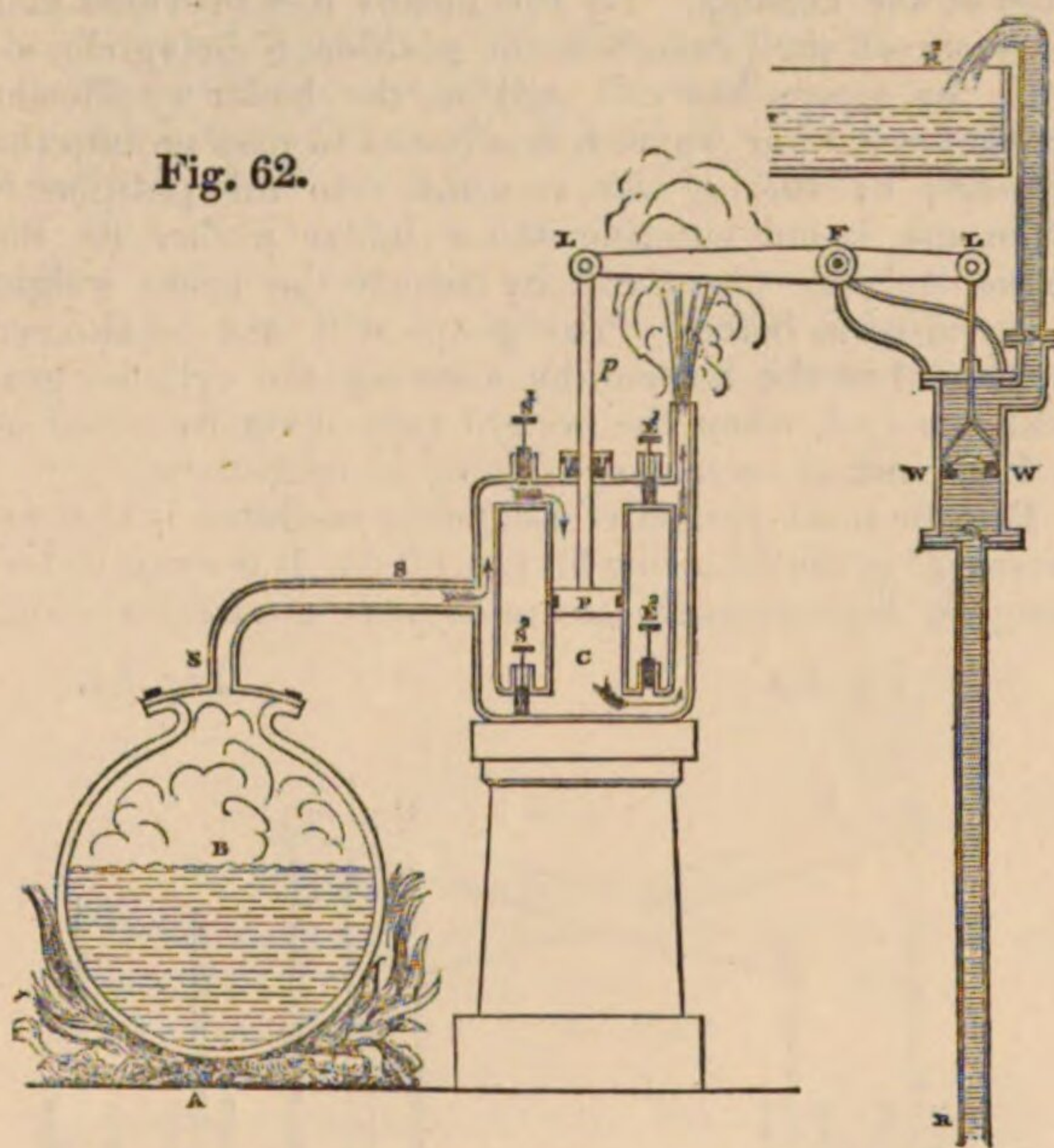
might be efficiently used without any alteration at the present day, only the modern machines are calculated to do the work with a smaller expenditure of fuel. Two pumps for raising water are directly worked by steam, by connecting the handles of the pumps with the pistons of two high-pressure cylinders, in such a manner, that when the pistons are raised by the steam the water is forced up in the pump-pipe. T and V are the barrels of two pumps placed in a reservoir, from which water is raised through the joint-pipe K; G and H are the handles or levers by which the pumps are worked. The pistons of the steam cylinders C and D are attached to the ends of the levers. In figure 60, at A C the steam is shown in the act of entering into the cylinder C, and pushing up the end of the lever G, so as to force the water; and

Steam-Engine.
Modern High Pressure Steam-Engine.

in figure 61 the steam is shown entering into the cylinder D to work it. This change is effected by turning round the disc A F into the position R S, which reverses the passages, as will appear on examination. It is to be noticed, that while the steam is entering the cylinder C through A C, the steam from the cylinder D is escaping through E F into the open air; and that in the second sketch of the valves, the steam is passing into the cylinder D through A E, and passing out of the cylinder C through C F. The action of this *four-way stopcock* is very simple and beautiful, and deserves to be carefully studied. By continually turning it round in one direction, communications are simultaneously effected between the boiler and each of the cylinders alternately, and between each cylinder and the open air. We shall afterwards revert to this mechanism.

The modern steam-engine of high pressure is in many respects analogous to the machine of Leupold. It will be readily understood by the study of the few following illustrations. The engine is called double-acting, because

Fig. 62.



the steam not only enters the cylinder below the piston to raise it, but also above the piston forcibly to depress it. The boiler B is placed on the left of the figure; the pump, for raising water from the reservoir R to the reservoir R², is on the right of the figure; and the cylinder is placed in the middle. From the boiler a *steam-pipe* S S S¹ S² proceeds to the upper and lower parts of the cylinder C; and from the right hand side of the cylinder two short *eduction-pipes* E¹ and E² carry off the steam into the open air, after it has performed its duty. The piston P is accurately fitted into the cylinder, so as to be air and steam tight, and the piston-rod p is made to carry with it the end of the lever L F L, and work the pump W W. Perhaps the only difficulty that is felt in understanding the mechanism of the double-acting steam-engine, lies in the construction and operation of the valves. S¹ S² E¹ E² are four plugs, each capable of exactly filling up the passage in which it is placed, like S² E¹, or of being withdrawn from it, like S¹ E². Therefore it is evident that in figure 62, the steam has free access through the upper port S¹, into the cylinder above the piston, so as to press it down. In fig. 63, the case is shown reversed; the valve S¹ is shut down, allowing steam to enter only by S², the lower-valve, so as to enter at the bottom of the cylinder and force the piston up.

The arrangement of the eduction-valves E¹ and E² is also to be observed. In fig. 62, where S¹ is open and S² is shut, E² is also open, and E¹ is shut; so that, while steam enters freely by S¹ on the upper side of the piston, pressing it down, there is a free passage for escape of steam from the under side of the piston, by the bottom passage, through E² to the open air; and when the whole is reversed, as in fig. 63, the steam-valve S² at the bottom being opened for ingress of steam below the piston, E¹ gives free egress to what was formerly admitted above, so that it may now pass along the passage E¹ into the open air. Thus then, by opening and shutting alternately each of the two pairs of valves, first the under steam-valve and upper eduction-valve, and then the upper steam-valve and under eduction-valve, so as first to allow steam to enter above and escape below, and then to get in below and out above, the one pair being always shut when the others are open, the whole effect is accomplished.

It is an object of great importance to the precision of a machine's operation, that it should be automatic; that is to say, that it should not require for its successful action the continual attention and unvarying assistance of an attendant. In the machine which we have just described, the valves are opened and shut by the attendant. With the following simple mechanism the valves are opened and shut by the machine itself:—

Fig. 64.

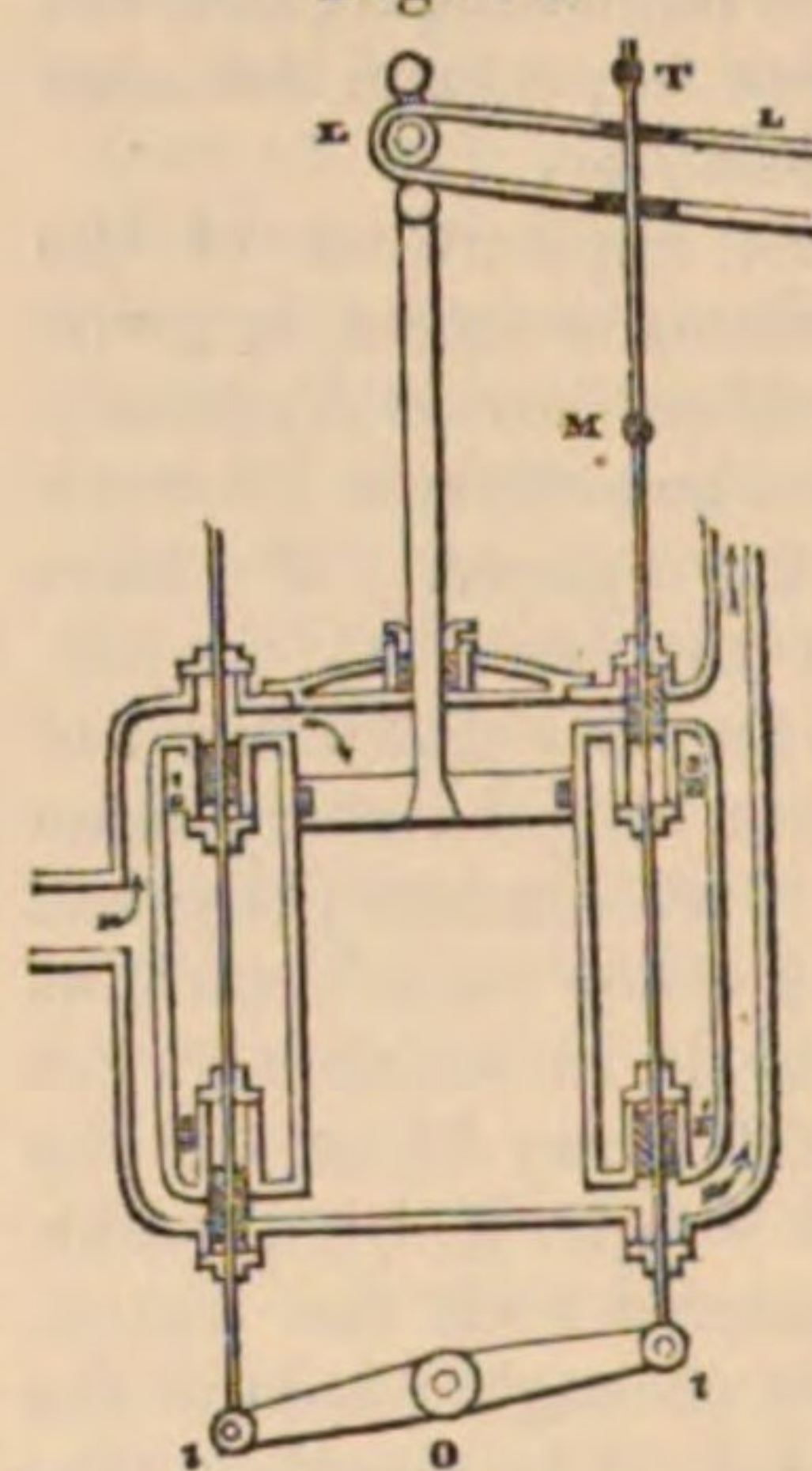
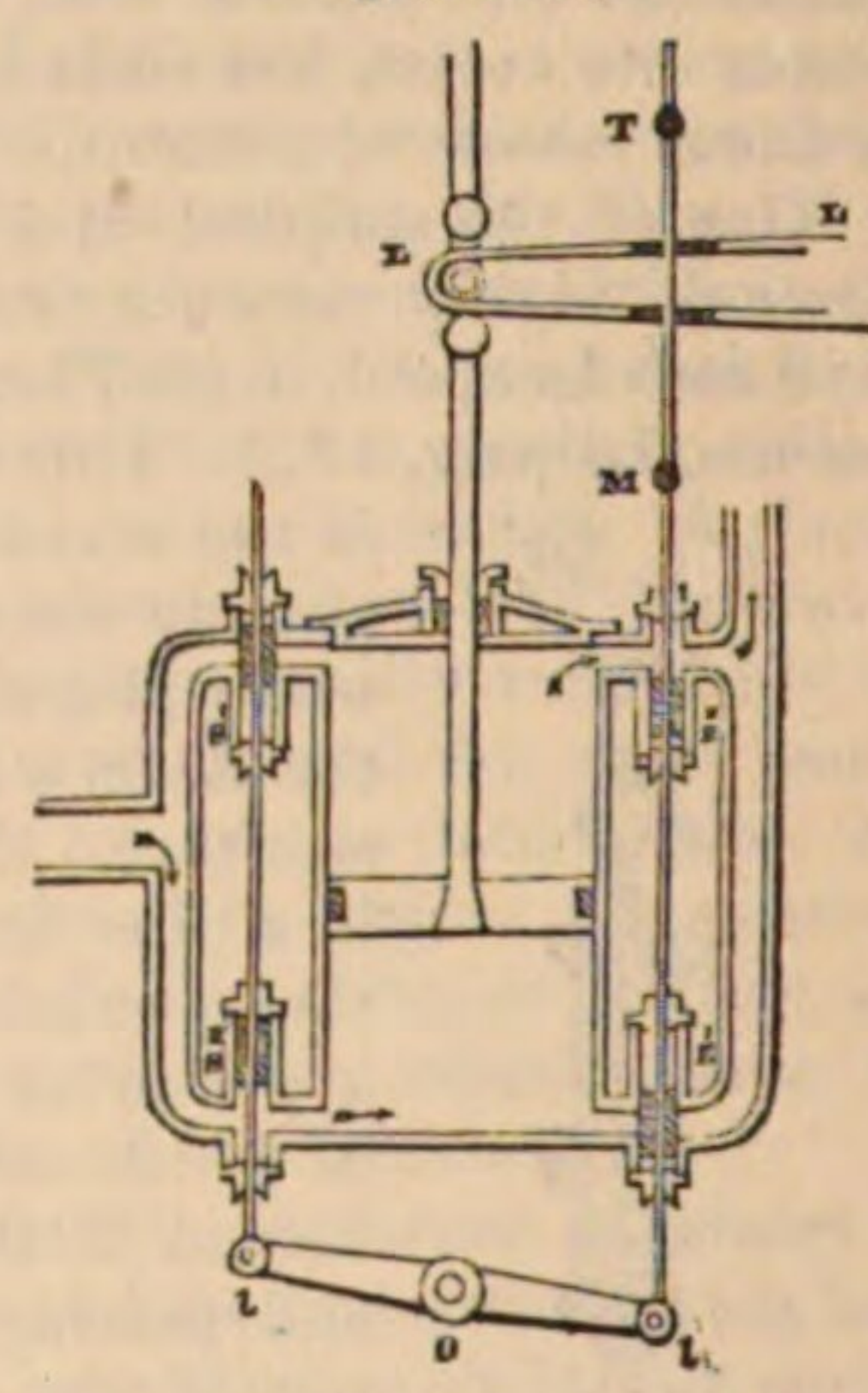
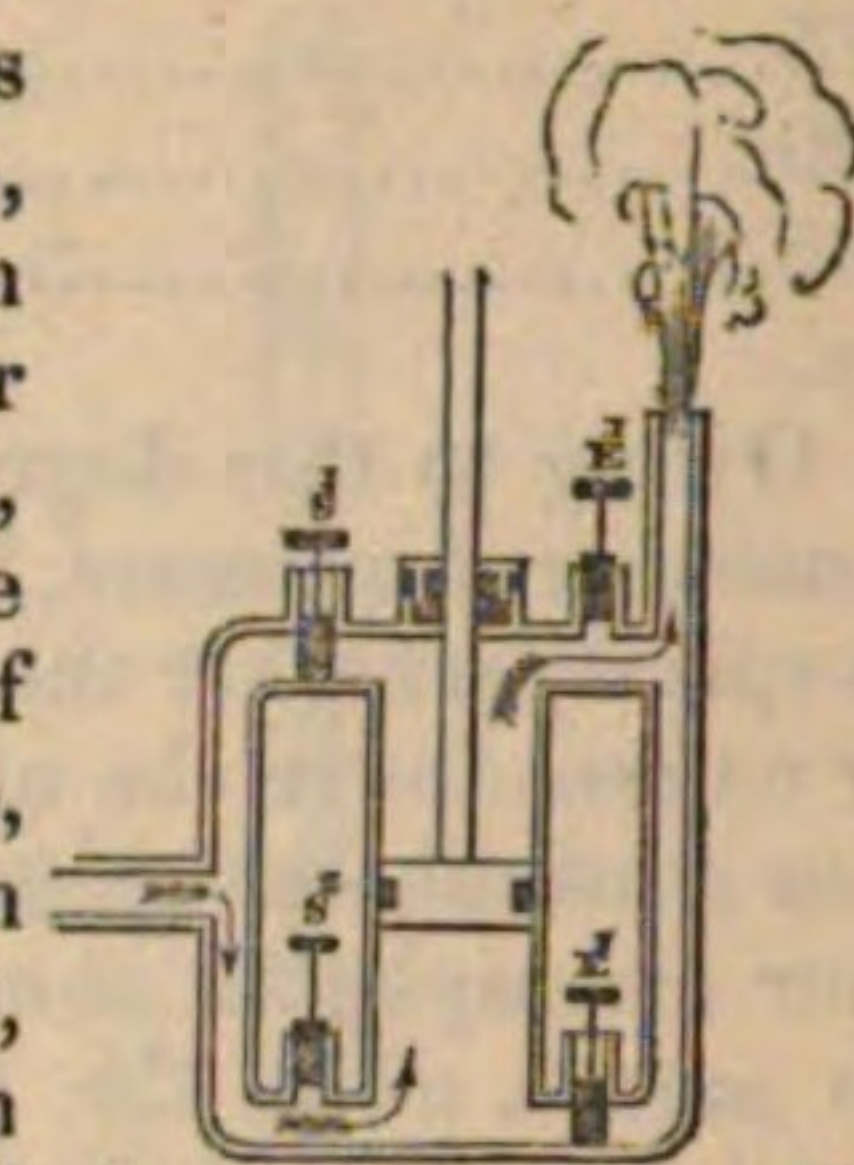


Fig. 65.



The two valves S¹ and S² are connected together by a straight rod, and the two eduction-valves E¹ E² by another straight rod; these valve-rods are made to rest on opposite ends of a lever l l, which turns on a centre O. By this simple arrangement it is brought about that the pair of valves S¹ S² being depressed, as in fig. 64, the other pair E¹ E² are raised; but when, as in fig. 65, S¹ S² are raised, E¹ and E² are depressed, while at the intermediate position both are situated similarly to each other. In the next place it is to be noticed that the rod E¹ E² is prolonged to T upwards, and that it carries two projections fixed to it at M and T. These projections are struck by the lever L L as it rises and falls. When in fig. 64, the lever is making its downward stroke, it comes on the plug M; and pushes it down, first into the middle position, and then into the position of fig. 65. The steam then entering below, raises up the piston to the top of the cylinder, and with it raises also the lever, which striking on the upper plug T, carries it upwards, raising the eduction valves E¹ E², and allowing the opposite valves

Fig. 63.



Steam-Engine.
High Pressure Engine.

Steam-Engine.
High Pressure Engine.

S^1S^2 to descend into the position of fig. 64, as at first. This operation being repeated, so that at the end of each upward and downward stroke, the descent and ascent of the piston and lever prepare the valves for producing the inverse effect, and giving the next succeeding stroke, the machine becomes independent and automatic. It is rather curious that these simple valves, now described, are the latest improvements that have been introduced in the steam-engine.

Fourway Cock.

Considerable ingenuity has been expended on the valves and passages of the steam-engine, for the purpose of forming all these communications by means of a couple of passages, instead of four. The following diagrams are designed to explain the manner in which this has been effected, by means of a four-way cock, similar to that introduced by Leupold into his high-pressure engine. For this purpose the steam-pipe S, the eduction-pipe E, and the pipes of the upper and lower ends of the cylinder, communicating with it above A and below B the piston, are all brought to the circumference of a single circle, so as to form a St George's cross, as in fig. 66. A metallic circular disc O P O B, with two curved channels communicating at successive quadrants of a circle, as shown in fig. 67, is inserted in this circle, so as to fit it exactly, and to be moved round by a protruding handle H. In fig. 68, this valve is represented *in situ*, a communication being formed from S to A, and the other from B to E; and, in fig. 69, the handle being pushed

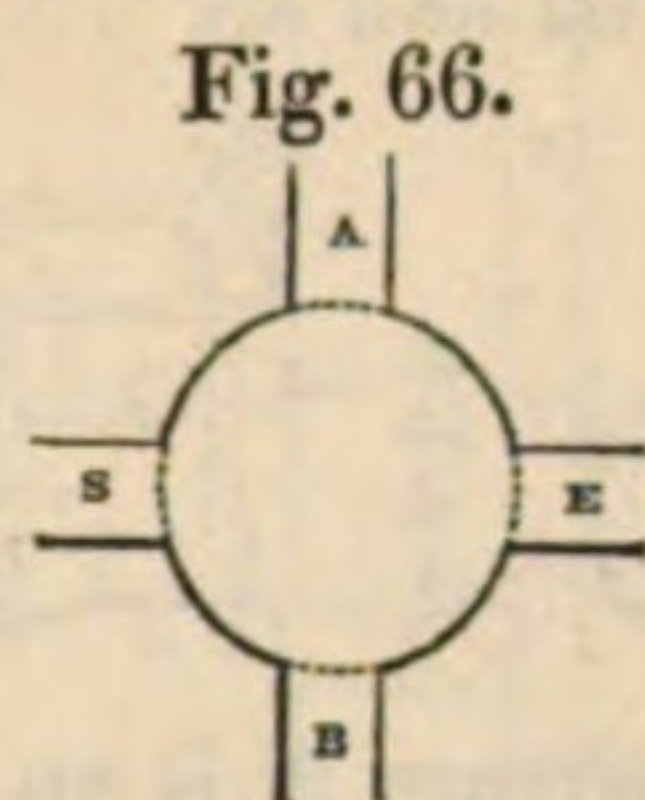


Fig. 66.

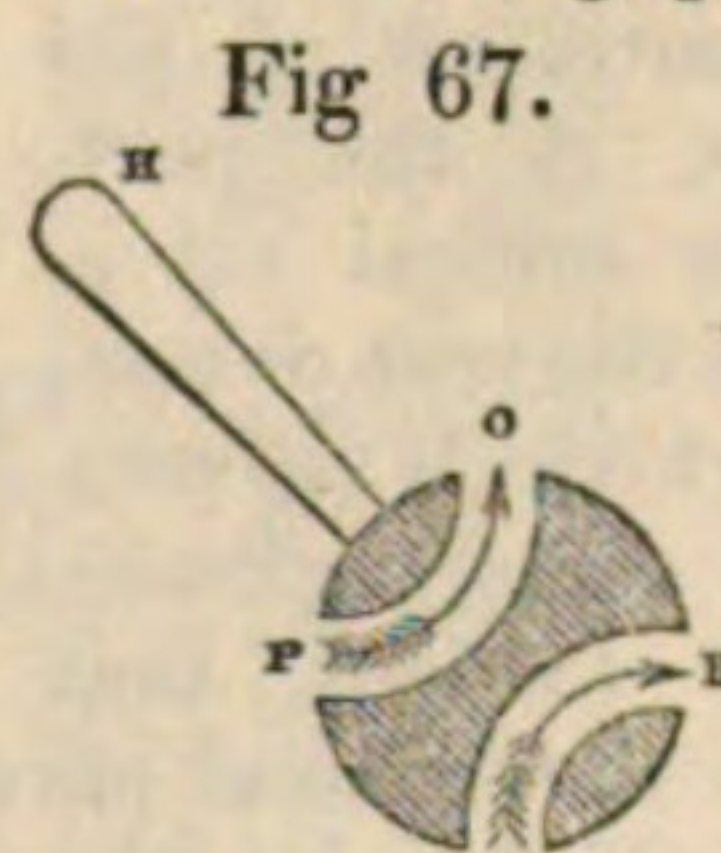


Fig. 67.

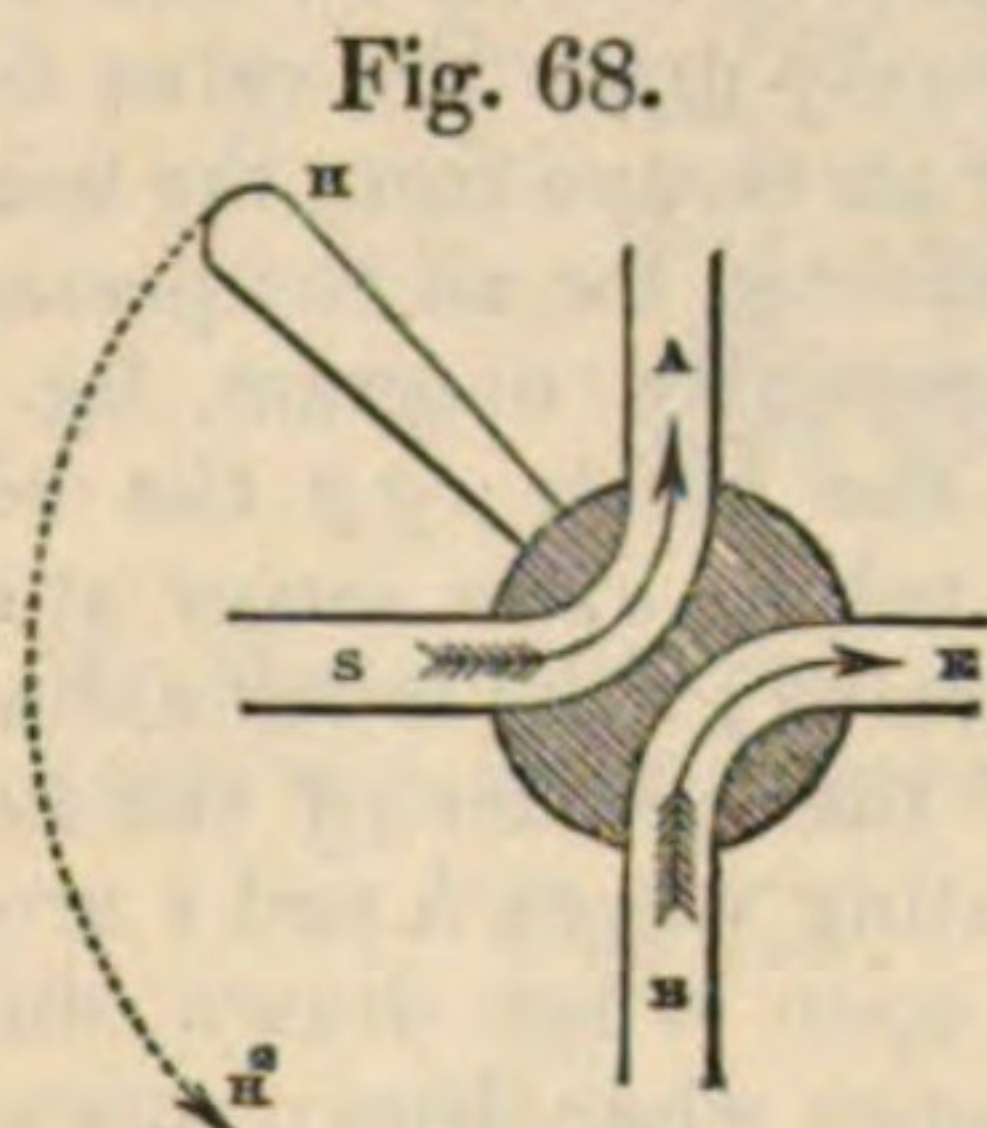


Fig. 68.

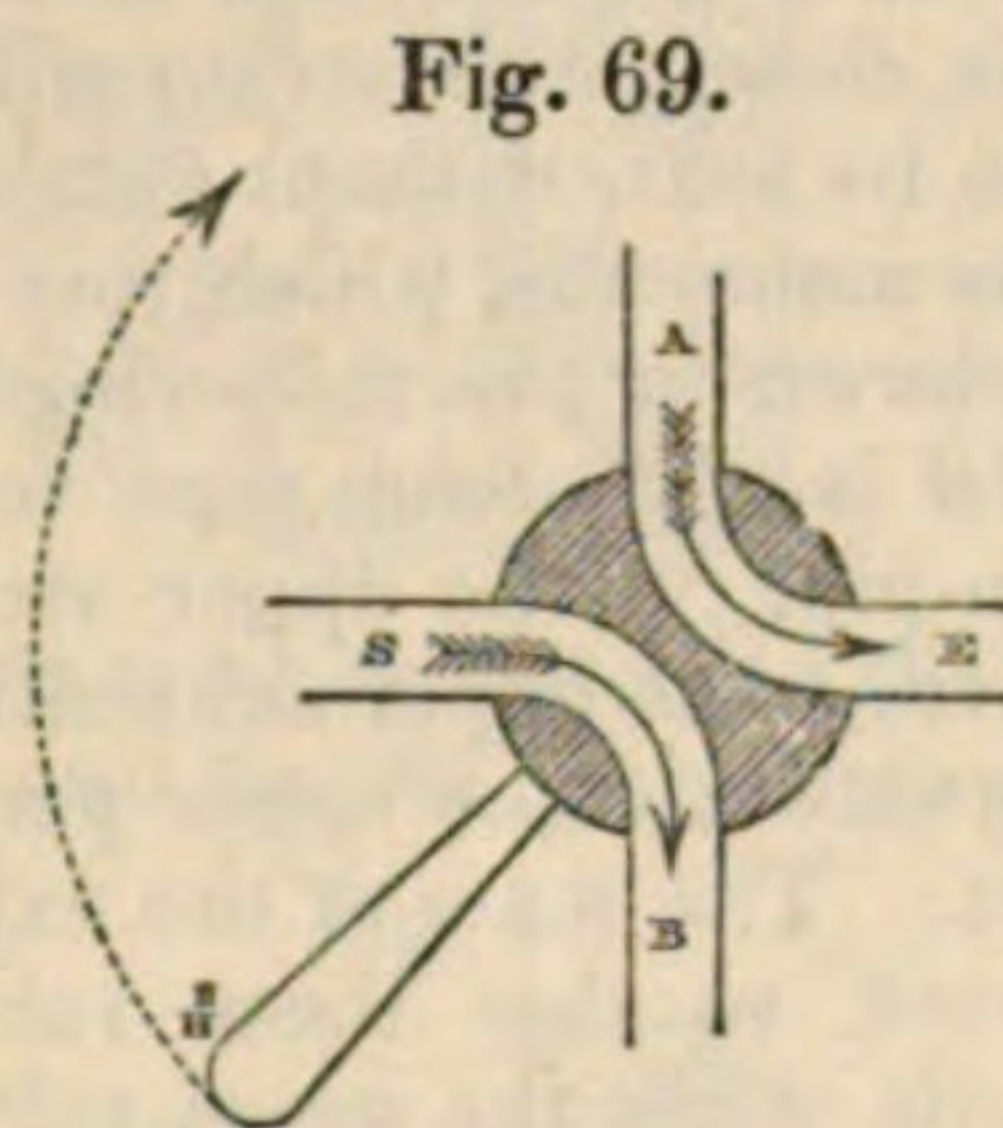


Fig. 69.

down, a communication is made betwixt S and B, and between A and E. The means of effecting this communication is given in fig. 70.

A vertical rod T T² being suspended from the end of the great lever, with two plugs T T², by means of which the handle H of the valve is raised, in that position the steam enters at S and passes up through the superior passage into the top of the cylinder, forcing the piston down, while the steam already below the piston finds free egress, along the inferior passage B, through the valve, and escapes at the eduction-pipe E into the open air.

Just before the piston gets to the bottom of its stroke, the plug T strikes the handle H into the position H². The steam before let in above the piston suddenly escapes by the port A through the valve into the eduction-pipe E, while by the same motion a connexion has been effected

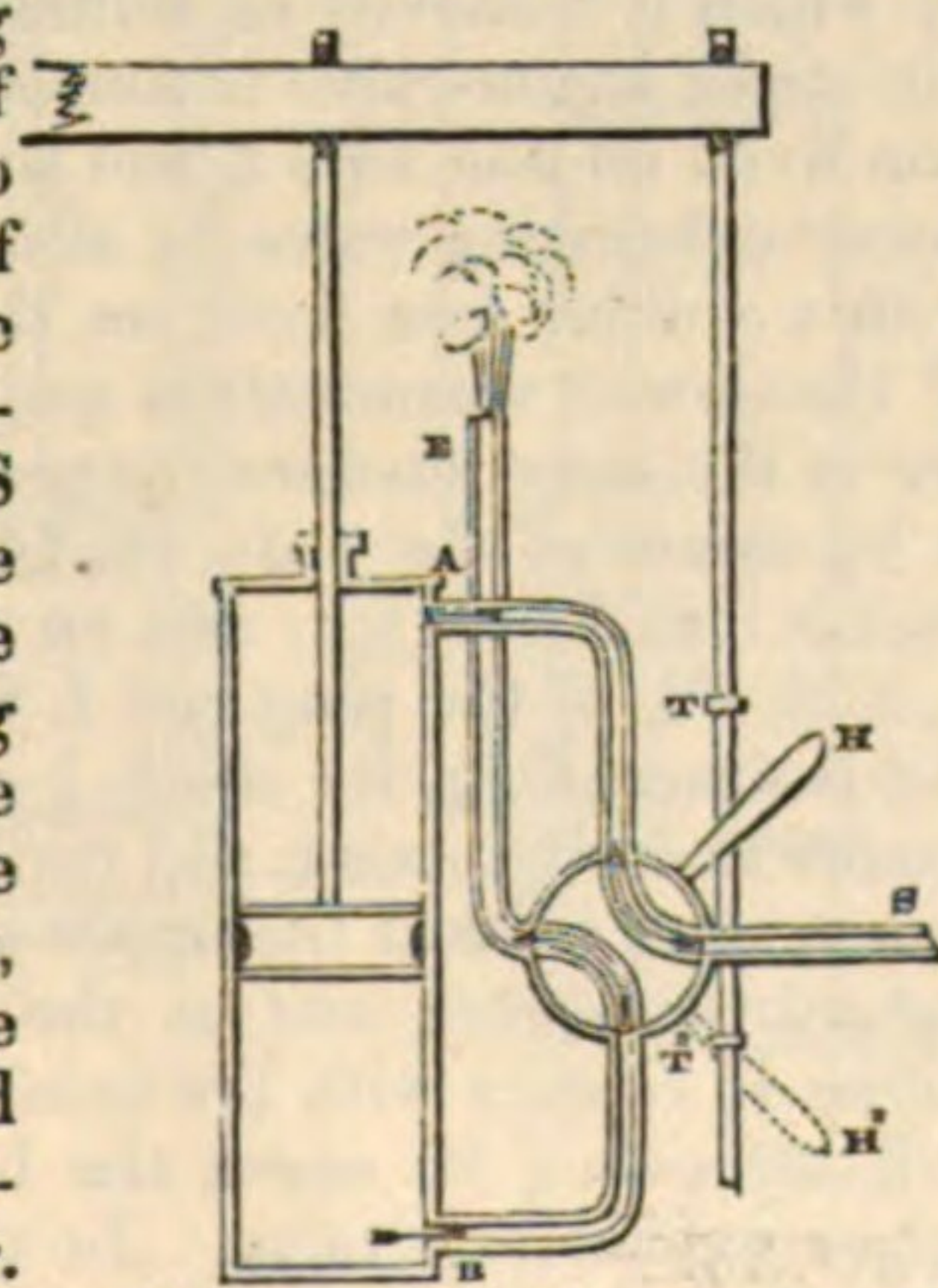


Fig. 70.

between S and B, so that the steam now enters below the piston, again to raise it up until the plug T² strikes the handle H² upwards once more into the position H as at first, when the piston once more descends; and this process is repeated to the end.

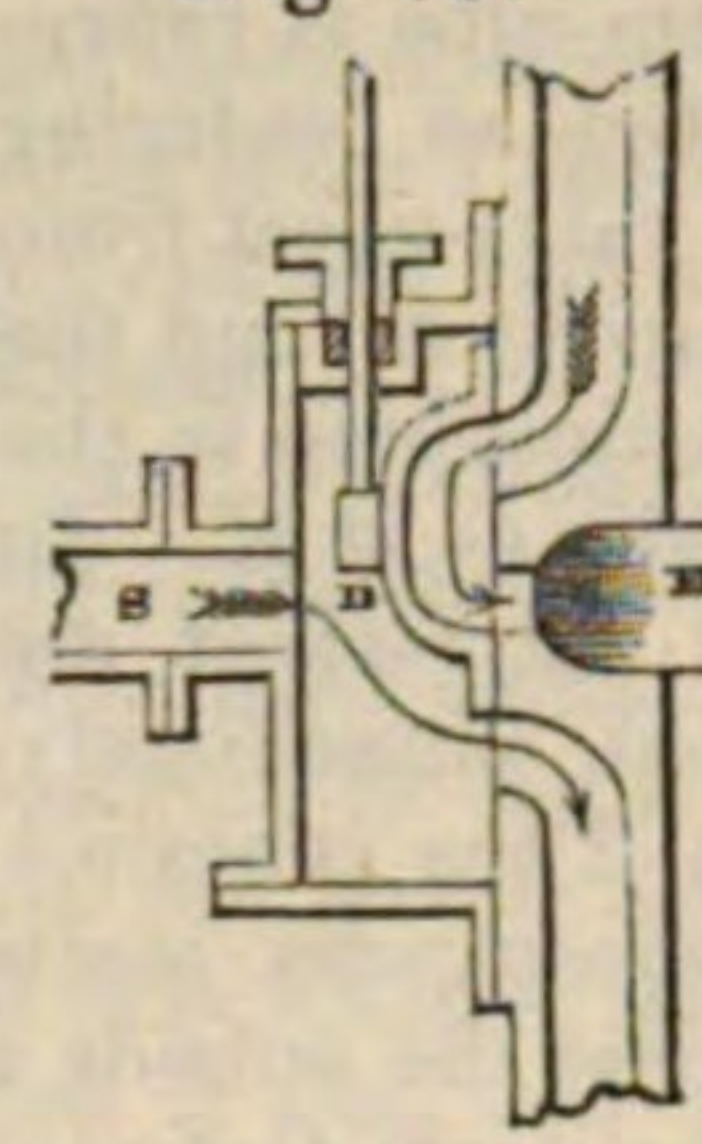
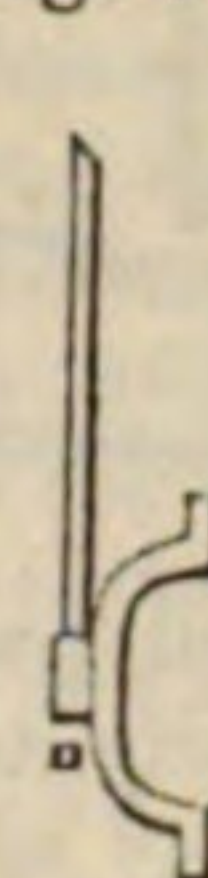
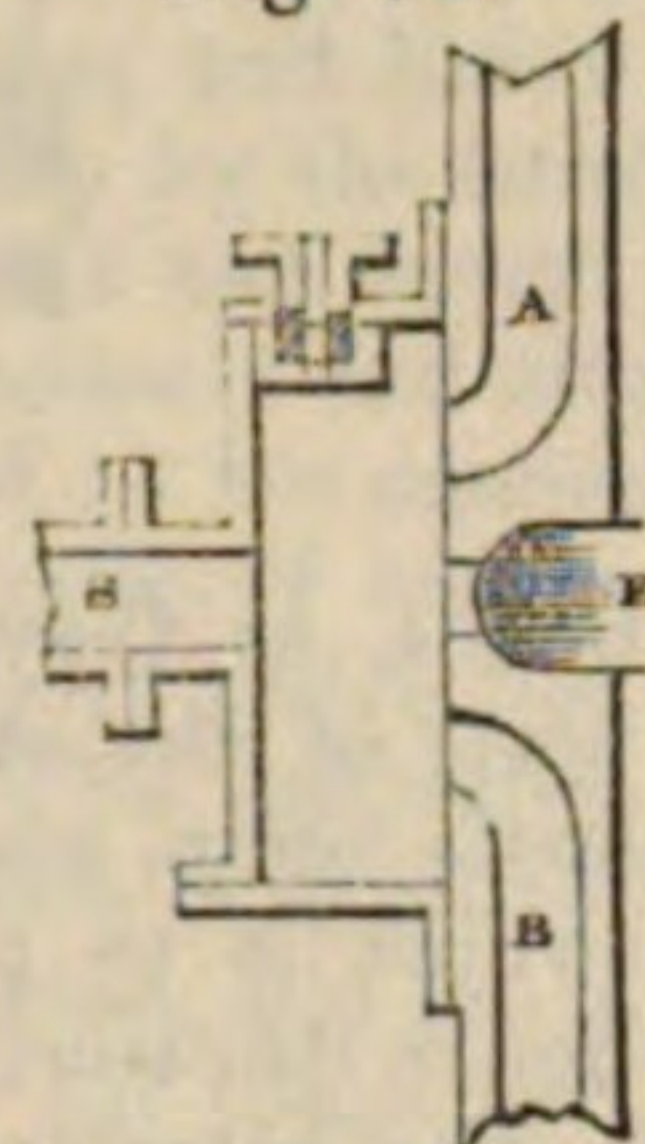
We shall next describe a kind of valve which is more commonly in use than either of the former, and by which the changes in the direction of the steam are still more

Steam-Engine.
Slide Valves.

Fig. 71.

Fig. 72.

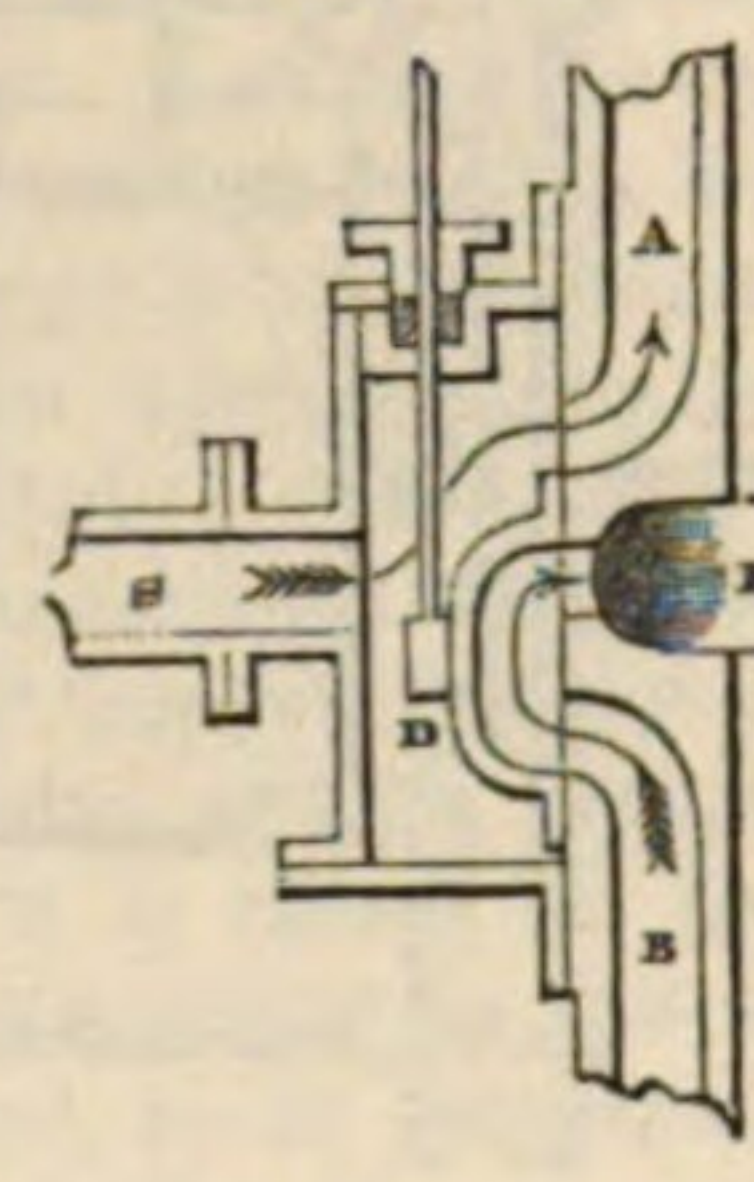
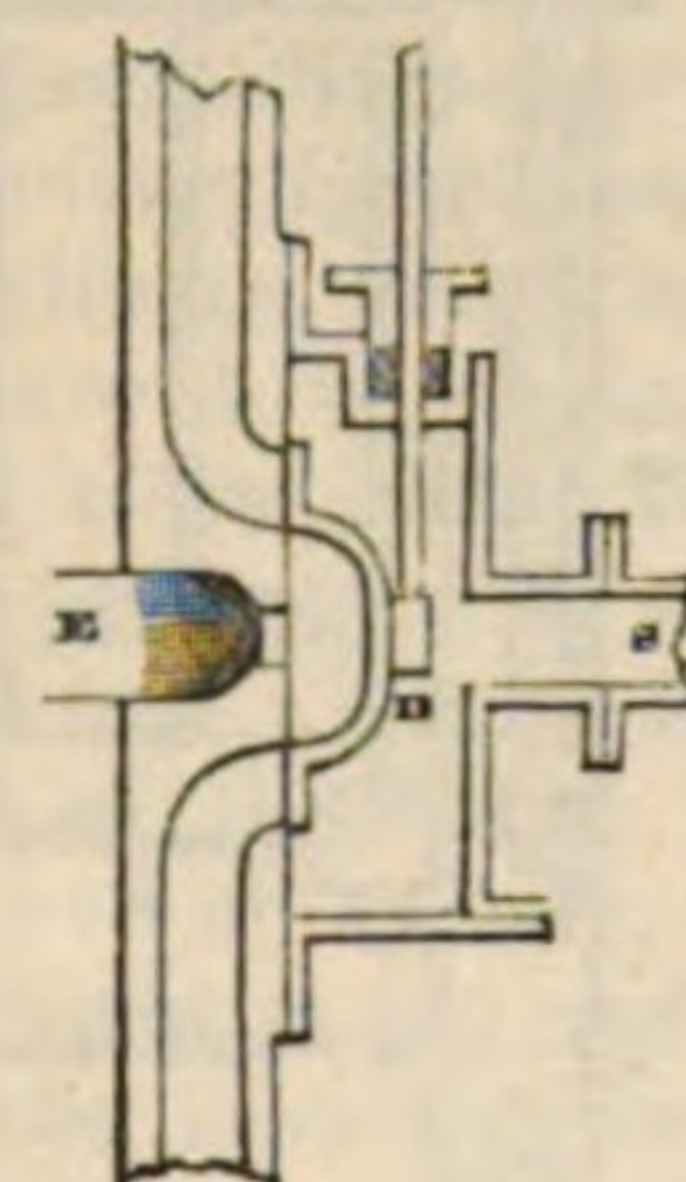
Fig. 73.



simply effected. In this case all the four passages are united in a square box called a valve-box, or valve-chest, as in fig. 71; S E A B being the steam, eduction, upper, and lower passages. Into this box is introduced a

Fig. 74.

Fig. 75.



small valve or cover D, fig. 72, which is of such a size as at one time to leave open only one of the three openings on the right; so that, by covering two of the openings, A and E, as in fig. 73, the steam from S can only find its way through B into the lower part of the engine, while the steam already in the upper part of the cylinder can find its way, below the valve D, into the eduction-pipe E, so as to escape into the air. The valve is next shown in fig. 74 in its middle position, where all the three passages are closed, preparatory to reversing the direction of the steam, as in the third position when it slides from the upper part A, as is shown in fig. 75, so as to allow the steam to enter above the piston and press it down, while the steam formerly below the piston escapes into the air through the passage B, under the valve D, by the eduction-pipe E. This valve, named from its figure the D-valve, is also worked by the machine itself, either by some of its moving parts striking plugs on a rod which is fixed to the valve, or by some of the other apparatus which will afterwards be described.

Another form of valve is that called the long slide or long D-valve, the invention of Mr Murdoch, which gives the advantage of shutting off the steam, close to its ingress into the cylinder; and so saving what in the common short D-slide is lost in the passages from A and B to the ends of the cylinder. It is formed thus. The valve chest extends along the side of the cylinder. It is shown in fig. 76, without the valve. In figure 77 the long D-slide valve is shown separately. It is a pipe extending along the whole length of the cylinder. Towards the ends, this pipe is almost semicircular, its flat side which forms the diameter of the circle, being a narrow flat plate capable of covering the opening or port of the cylinder. This pipe is left open, and perfectly clear from one end to the other, so that steam

Steam-Engine.
Slide Valves.

may traverse it freely length-wise. The semicircular ends are polished, and rendered truly cylindrical, that the packing in the valve chest may embrace them perfectly. The steam-pipe is represented as entering the valve-chest from below at S, and the eduction-pipe in the middle as at E. In this valve-chest are placed packing-boxes, as they are called, immediately opposite to the ports of the cylinder. They contain a quantity of soft elastic hemp, soaked in oleaginous matter, the object of which is to press against the outside of the slide-valve when in its place, and make steam-tight partitions in the valve-chest between the middle and ends of the valve, so that no communication of steam can take place between the middle and the two ends.

Fig. 76.

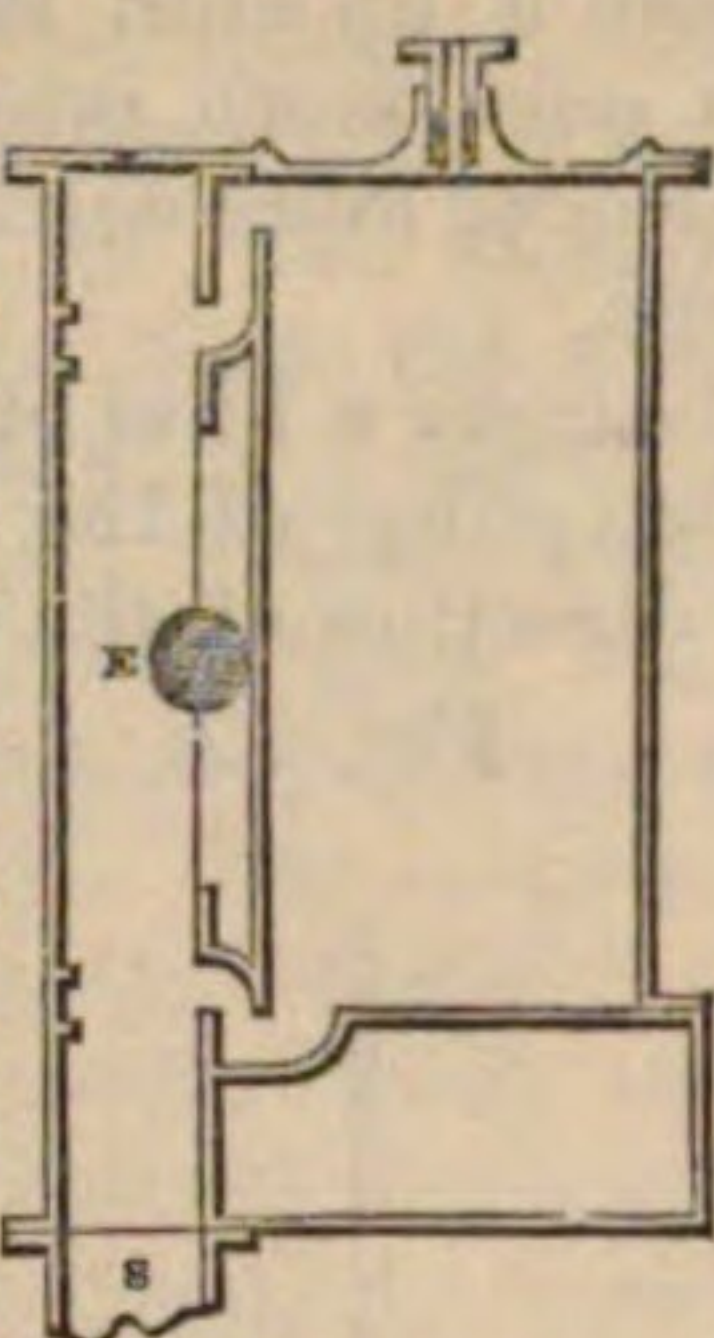
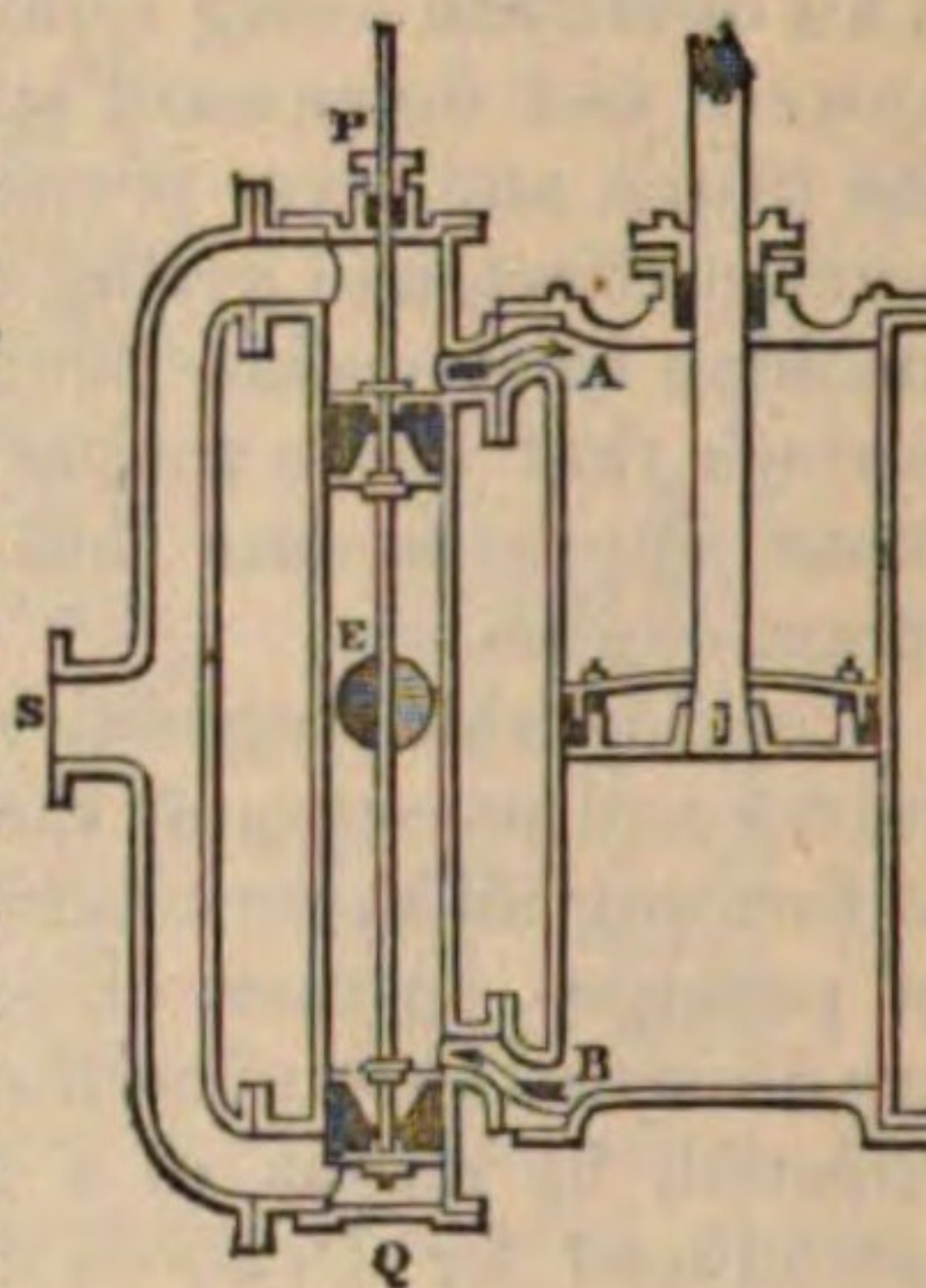


Fig. 77.



use in a considerable number of engines, and works well in those cases which we have had an opportunity of examining. The valve-chest is an upright cylindrical pipe P Q, the inside of which is bored truly cylindrical, and is exactly fitted by two metallic cylindrical plugs, which are ground so smooth in their places as to be steam-tight. It will be apparent from the figure that these two plugs being raised and depressed by the valve-rod which connects them, will effect the same purpose as the former valve.

Fig. 83.



Steam-Engine.

Fig. 78.

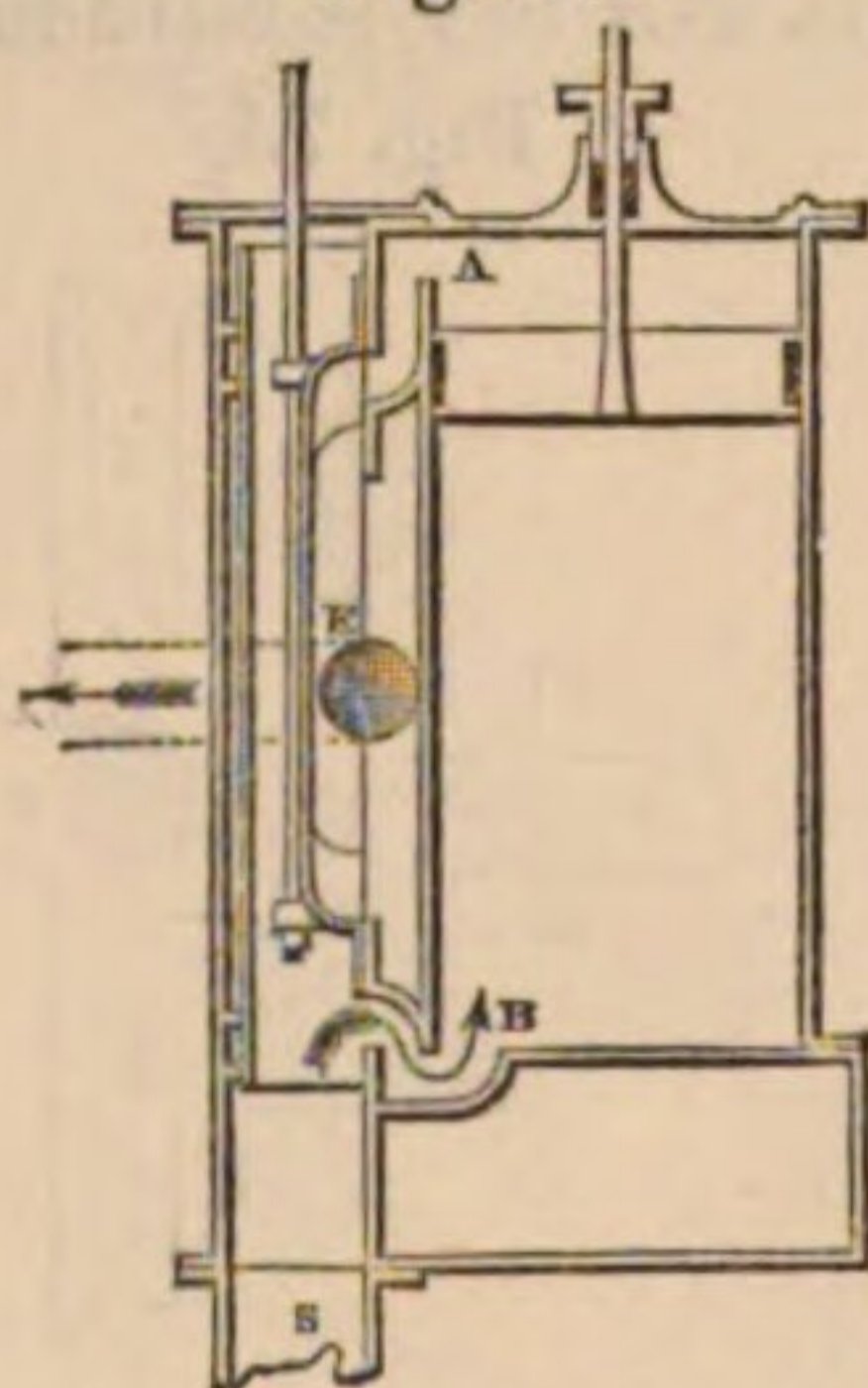
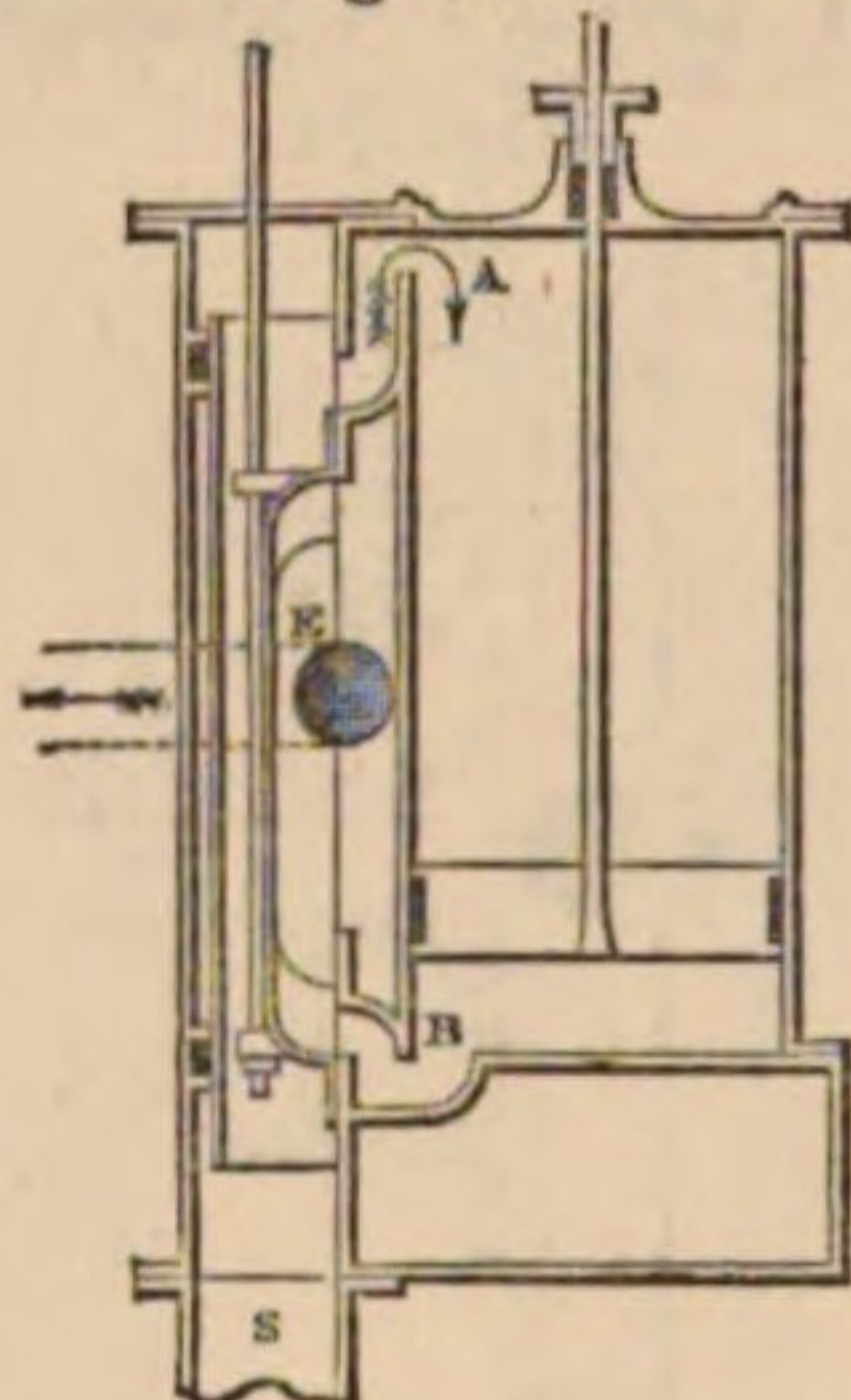


Fig. 79.



In the figures 78 and 79, the valve is shown *in situ*. In figure 79, the steam from S rises up along the centre of the slide, and enters the upper part A, while the steam in the under part of the cylinder has free egress through B to the eduction-pipe E. In figure 78, the steam has free access to the lower part B, while the steam already above the piston has free egress through the port A, through the eduction-pipe E. In this species of slide, there is scarcely any loss of steam in the passages, as it is cut off close to the cylinder.

Instead of the long D-slide, which is very heavy on a large scale, two short slides, similar to its two ends, and connected together by bars, have been used in the following form. Fig. 80 is a section of the slide, fig. 81, a

Fig. 80. Fig. 81.

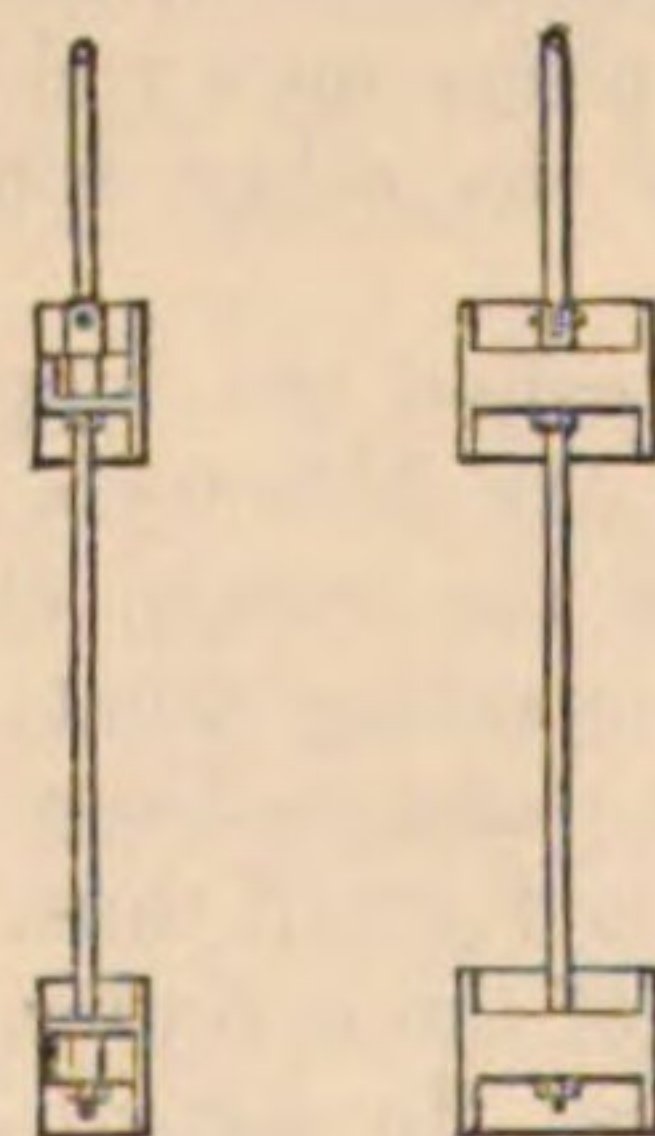
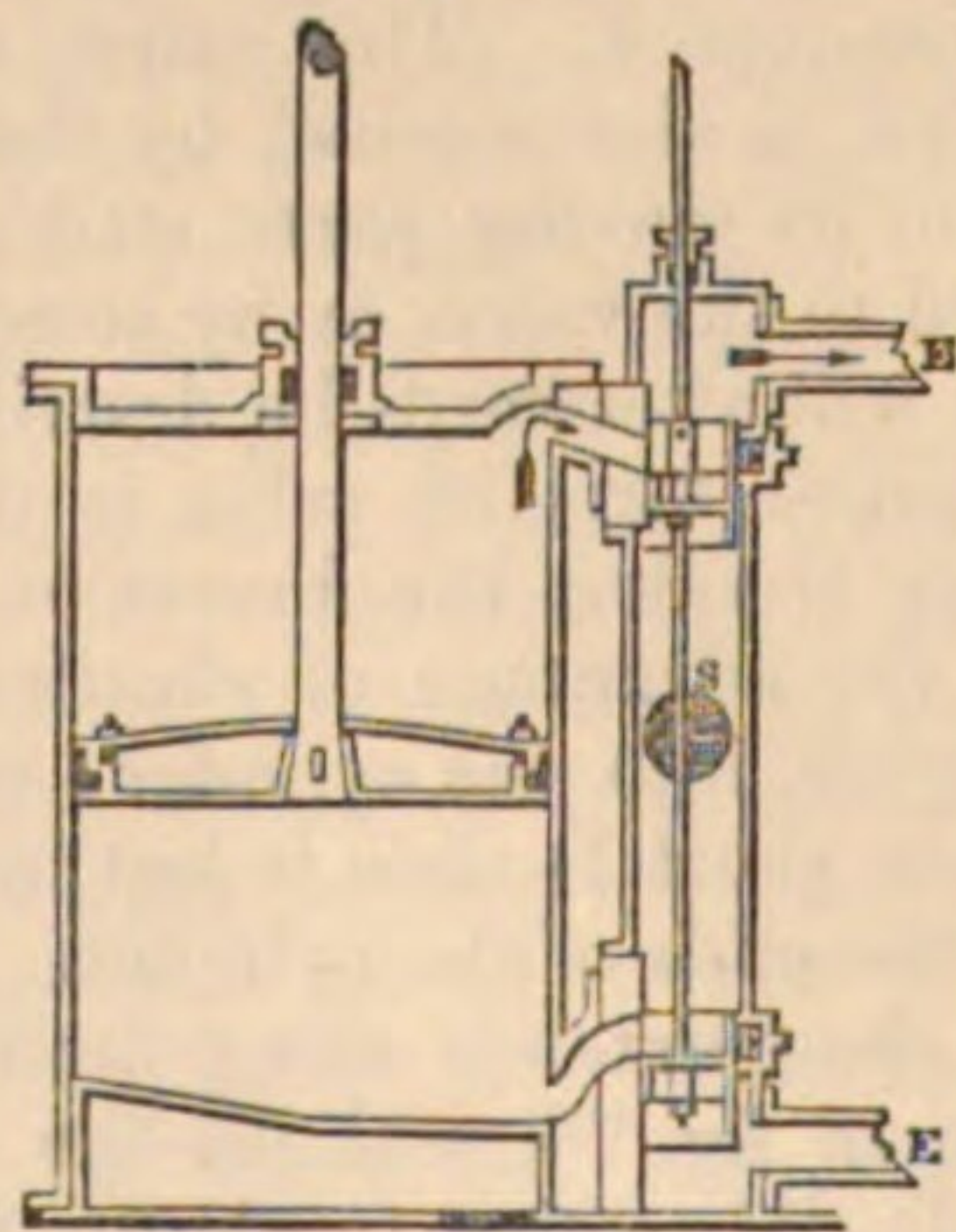


Fig. 82.



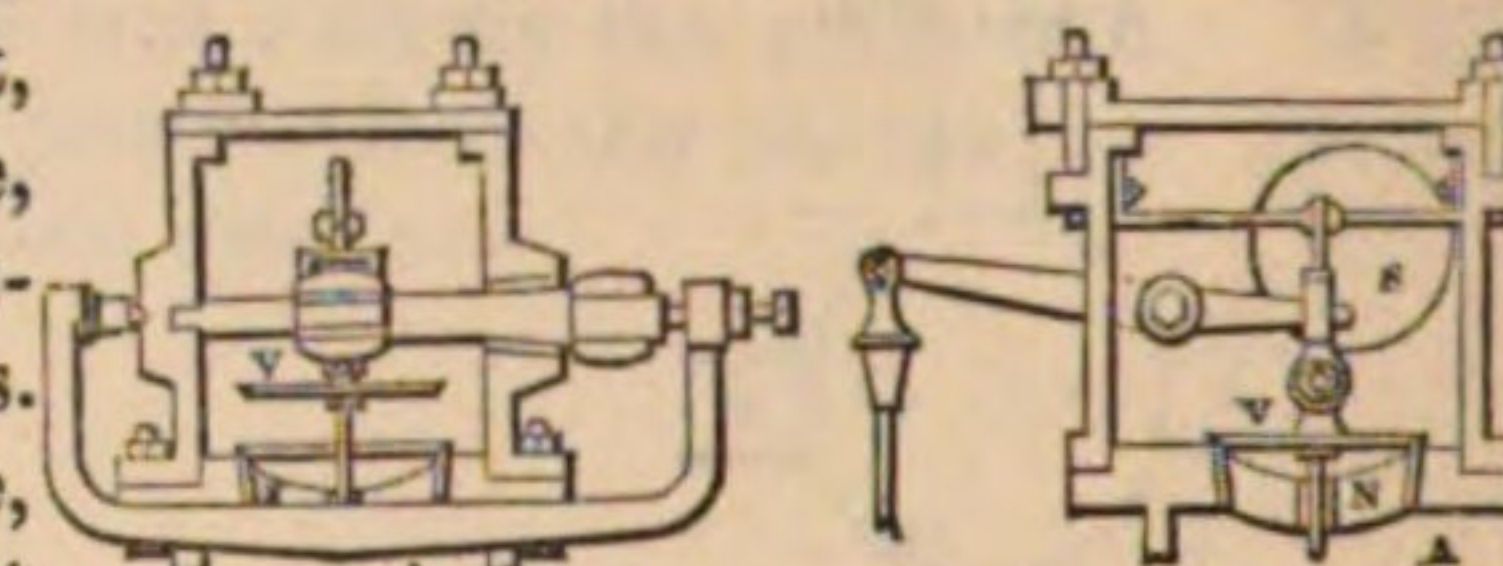
face view; and fig. 82, a section of the cylinder with the valves in their place.

In this case, however, there are two eduction-pipes E E instead of one, as formerly, and the steam-pipe enters between the valves.

A cylindrical slide-valve of the following form is in

The conical valve is a species of valve introduced by Mr Watt, and improved by his assistant Mr Murdoch, from whom the steam-engine of Watt has received many valuable appendages, and much of its practical perfection. It has been applied in two forms. Mr Watt's own form, the earlier one, is given in the following figures. For a single engine four valves are required. One of them is represented separately in figures 84, 85, which are vertical sections through the valve, at right angles to each other. The valve is shown open in fig. 84, and shut in 85. S is the entrance of the steam, A the port, V the conical valve, and N the seat or nozzle which it covers. On a cursory glance, it is evident that

Figs. 84 and 85.

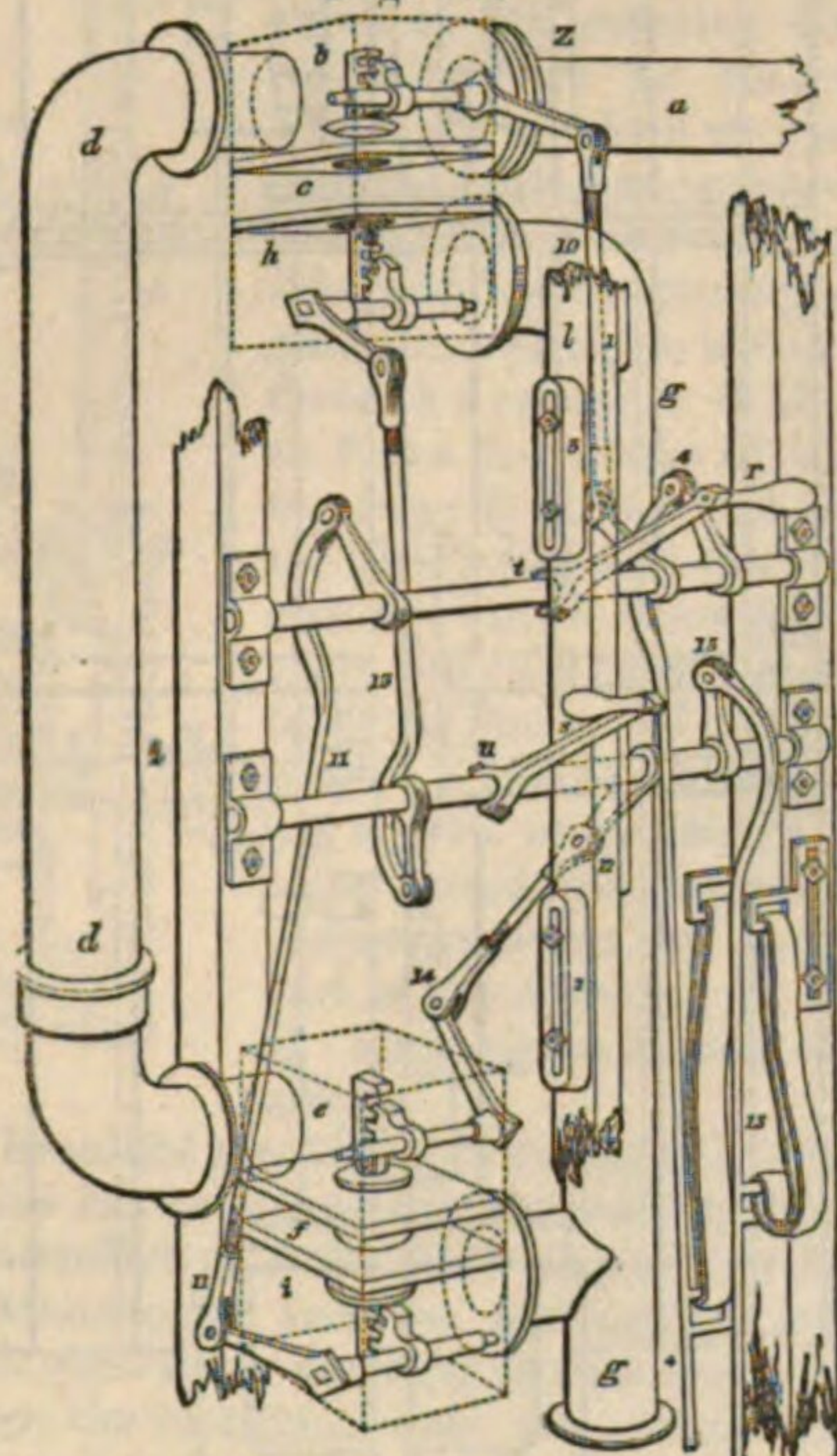


when the conical cover V of the aperture N is up, as in the first diagram, the steam has free entrance; and when it is closed, the steam will merely press the valve down into its seat, without obtaining an escape from the nozzle. The manner in which this is effected for all the passages, is shown in the following perspective diagram, fig. 86. *add* is the steam-pipe from the boiler; *gg* the eduction-pipe; *b* the upper steam-valve; *e* the lower steam-valve; *h* the upper exhausting valve; *i* the lower exhausting valve; *c* the upper part of the cylinder; *f* the lower part. The seats of the exhausting valves *h* and *i* are inverted, so that these valves open when drawn downwards, while the steam-valves open when drawn upwards. Each valve has a toothed rack attached to it, which is acted on by a toothed sector, fixed on an axis, whose end passes through the valve-box, and carries an arm or handle by which it is moved as follows:—the arm or handle of the upper steam-valve is connected by the rod 10 with an arm fixed on the axis *t*, and the arm on the axis of the lower exhausting valve is also connected by the rod 11 with a similar arm fixed on the same axis *t*. The arms of the lower steam-valves and upper exhausting valves are in the same manner connected with arms on the axis *u*, by means of the rods 13, 14. These axes *t*, *u*, carry each a handle *tr*, *us*; and on these the plugs or chocks 1, 2, 3, 12, of the plug-rod *l*, 12, act. When the plug-rod is descending, its chock 1 comes in contact with the handle *tr* of the axis *t*, and depressing it, turns round the axis *t*, so as to shut the upper steam-valve and the lower exhausting valve; and at the same instant its chock 3 comes in contact with the handle *us* of the lower axis *u*, and depressing it, opens the lower steam-valve and the upper exhausting valve. In the upward motion of the plug-tree, the position of the handles are reversed by the chocks 12, 2. The axis *t* carries a short lever 4, to the end of which there is a weight hung through the rod 4 4. When the valves connected with the axis *t* are opened, this weight keeps them open; but is prevented from open-

Steam-Engine.
Conical Valves.

ing them too far by the strap attached to the rod, as seen in the figure. The lower axis *u* has a similar apparatus, 15, 15, for the same purpose. It remains to notice how the exhausting valves are prevented from being opened by the pressure of the steam. The rods which connect the arms on the axes of the valves with the arms on the axes *t u*, it will be observed, are bent at one extremity in such a manner as that when the valves are shut, the connecting rods and the arms on the axes *t* and *u* fall into the same straight line, as is seen in the case of the upper exhausting valve in the figure. In this condition the arms of the axes *t* and *u* cannot act as levers in turning these axes round, and the valves are thus effectually locked until released by the action of the chocks upon the handles *r s*.

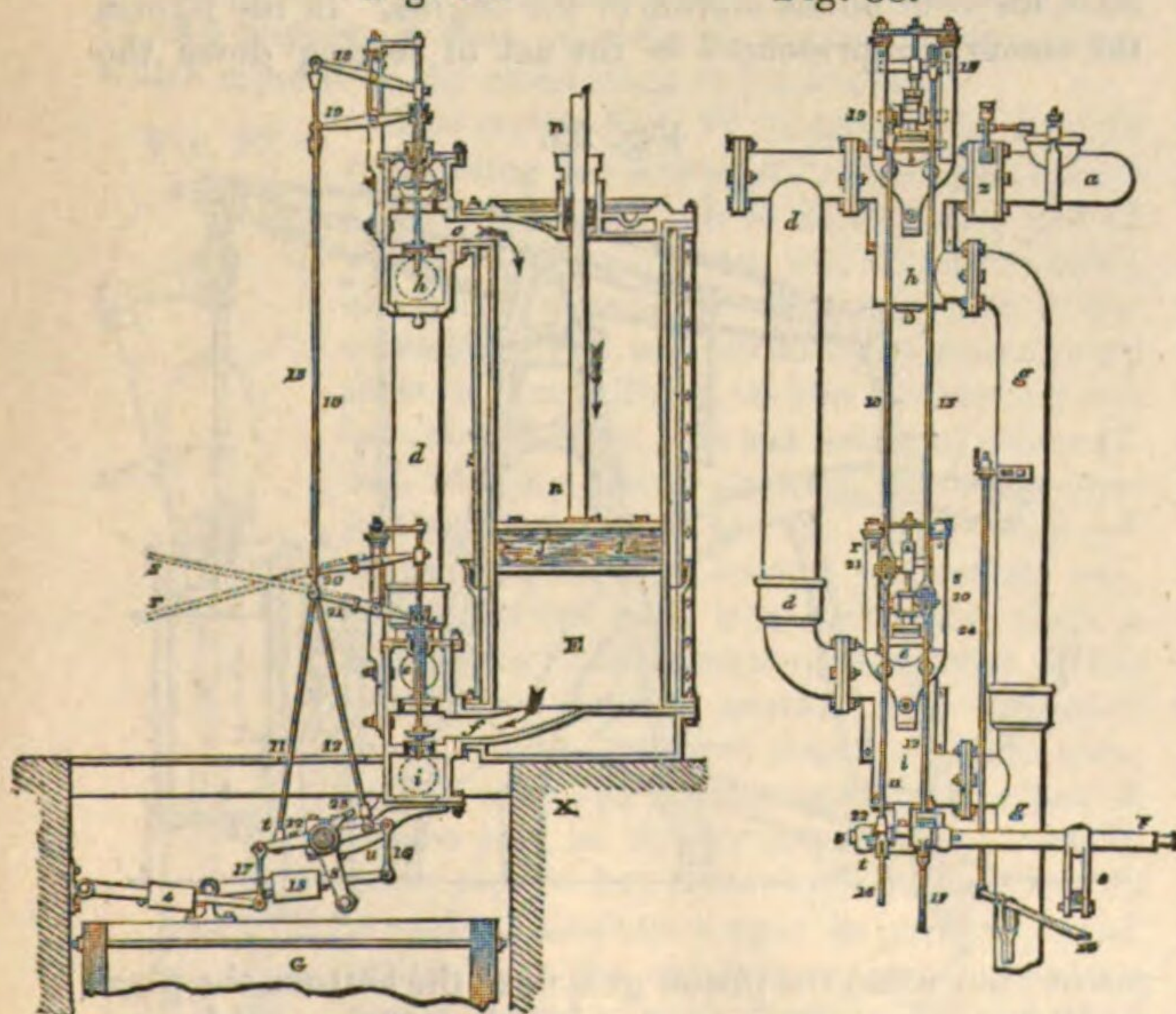
Fig. 86.



Mr Murdoch's conical valve is represented in the next figures: fig. 87 a side view, and fig. 88 a front view.

Fig. 87.

Fig. 88.



a d d are steam-pipes, and *g g g* eduction-pipes as formerly; *c* being the upper port of the cylinder, and *f* the bottom port; *b* and *e* the top and bottom steam-valves, *h*

VOL. XX.

and *i* the top and bottom eduction-valves. The steam-valves *b* and *e* are raised or lowered by hollow rods or tubes, through which the spindles or rods of the eduction valves *h i* work freely without interference. A rod 10 joins the short levers 19, 20 of the valves *b e* together, and another rod 13 joins the levers of the valves 18 and 21 together; so that by inserting into sockets, formed on the ends of the levers 20 21, the bars *r s*, shown by dotted lines, and by using them as lever handles, the upper steam and lower eduction-valves are opened simultaneously by the handle *r*, and by the other lever *s* the lower steam and upper eduction-valves are opened also simultaneously and alternately with the former. The rods 10 and 13 are connected by the rods 11 and 12, with an apparatus of levers and weights, acting through an axis at 22, by which the valves are retained in their seats.

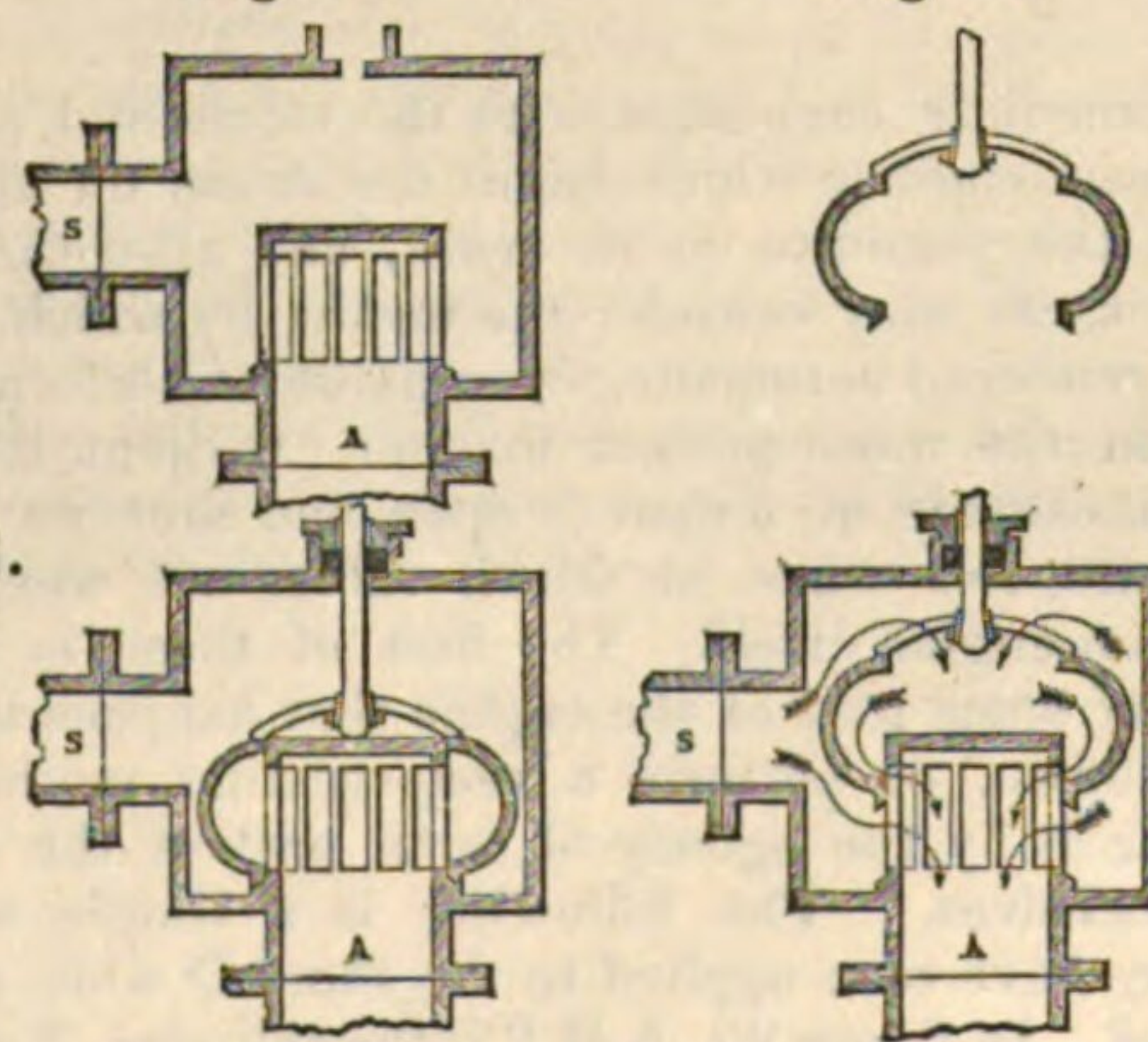
The last valve which we shall describe is the crown-valve, or equilibrium-valve, which is in use on the Cornish engine, and has also been introduced into rotative engines by Mr Fairbairn, and Messrs Caird & Co., and which deserves to be better known than it is. Its value consists in effecting a large opening, and requiring little force to work it, while large valves of the common sort are heavy, or are so much pressed in one direction by the steam as to require great force to work them. The valve has been called the crown-valve, from the resemblance of its appearance to that of a diadem. Let there be conceived a chamber, fig. 89, out of which an aperture *A* leads into the cylinder, and into which a pipe *S* brings steam. The aperture *A* is surrounded by an upright ring or collar rising a few inches into the chamber, which ring is on all sides perforated by slits of considerable size, but closed at the top. The next figure, 90, represents the crown or cover of this valve, which is also a ring attached to a steel rod or spindle, by which it is raised or depressed. All round at top and bottom, the collar in the chamber and the crown-valve are ground, so as accurately to fit each other. The next diagram, fig. 91, represents the valve on its seat, and closed on all sides, so that no steam can find admittance; and fig. 92 represents it open or raised up from its seat, with steam entering freely on every side.

Fig. 89.

Fig. 90.

Fig. 91.

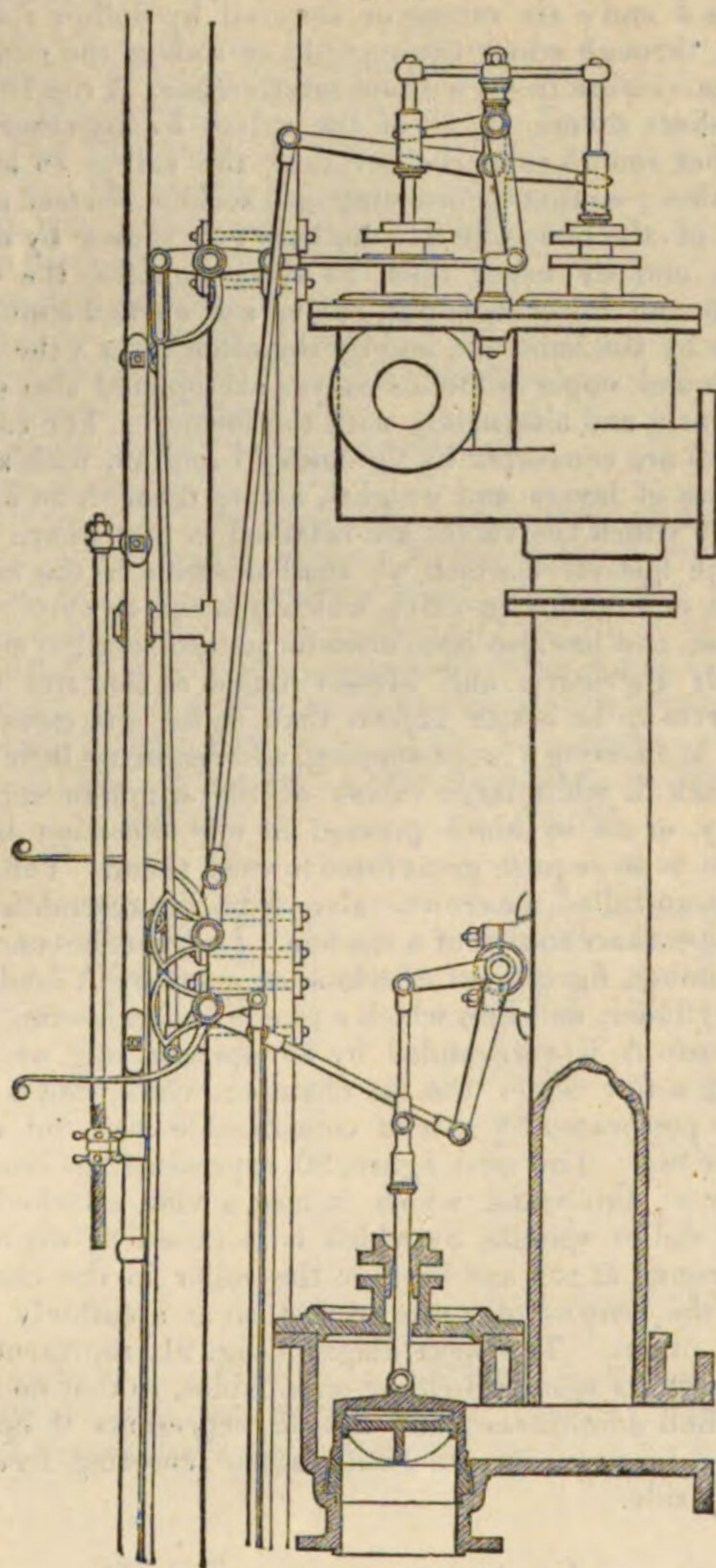
Fig. 92.



These valves are arranged in a manner similar to the common conical valves, and work in the same way, four of them being used in a single engine, instead of four conical valves as in fig. 86. The following diagram shows the valves and valve-gear of a Cornish steam-engine, with the gear for working the valves either by the hand or with the pump-rod of the steam-engine. It is very perfect, and deserves the study of the intelligent engineer. The valves are equilibrium valves, such as we have already described. Although we cannot here enter into a detailed description of the mechanism, the engineer will at once understand it from the drawing.

4 N

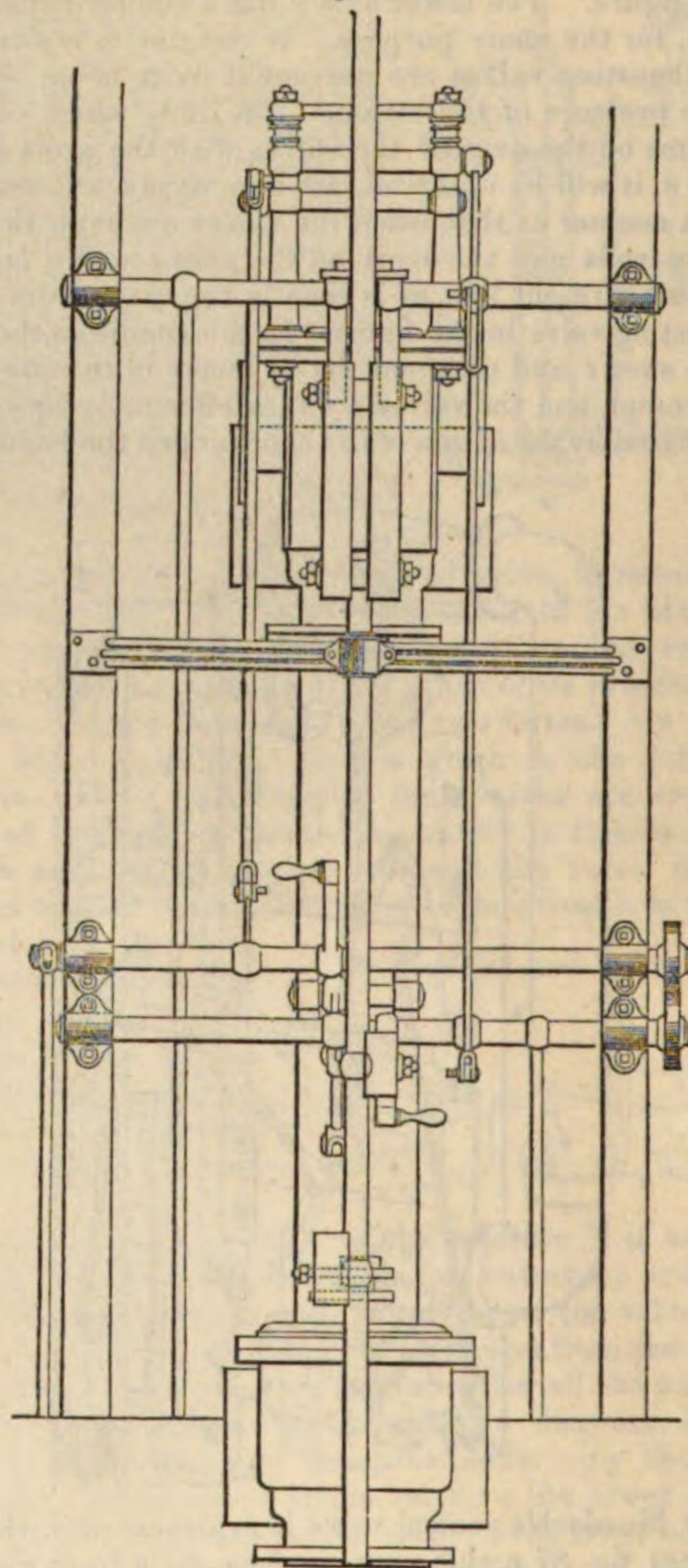
Fig. 93.



Valve gear.

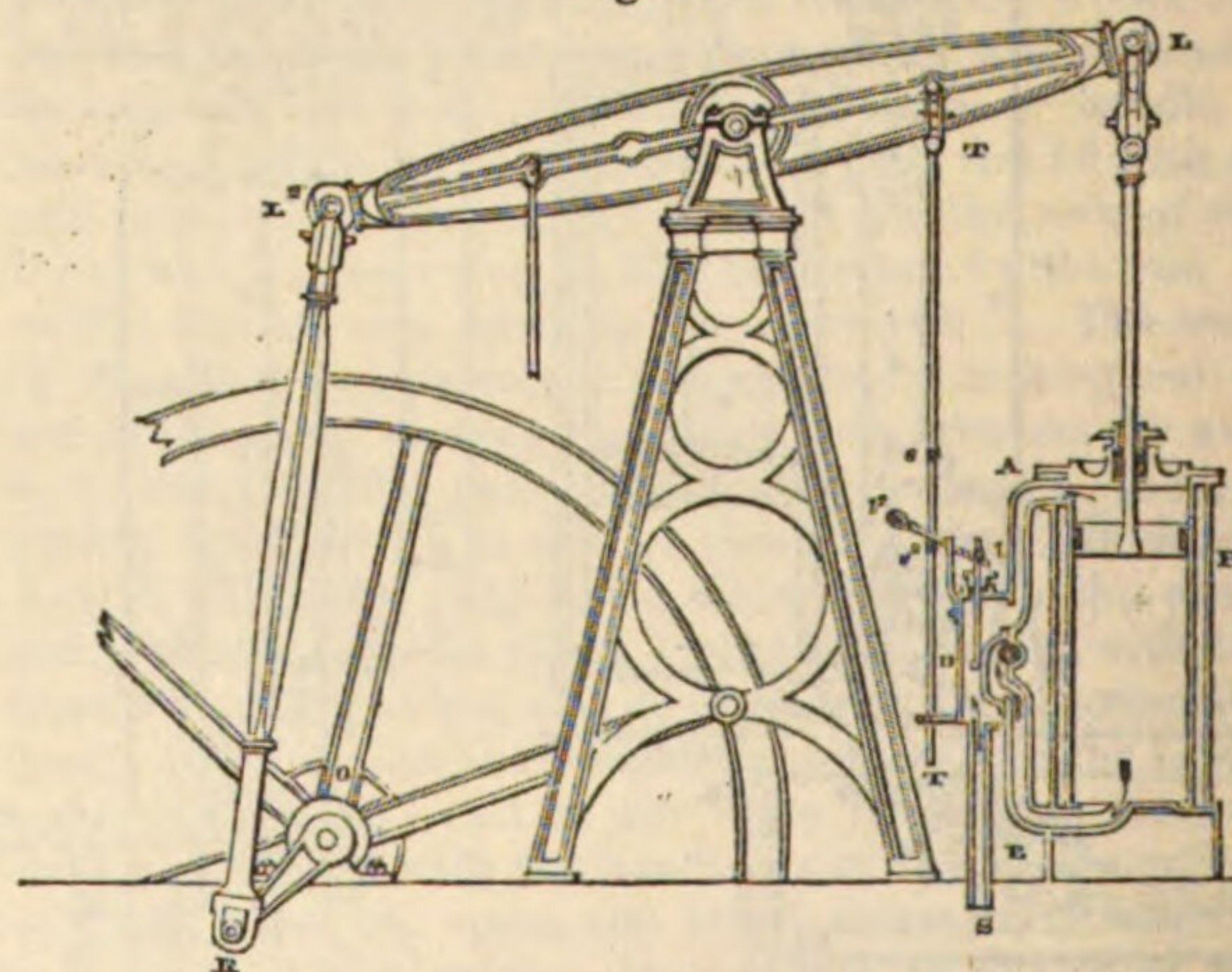
In immediate connexion with the valves and passages of a steam-engine, which admit the steam on alternate sides of the piston to do its work, and afterwards discharge it, we may consider the means by which the engine is rendered automatic, or capable of performing its labour in the most perfect manner, without the continual assistance of a man to open and shut its valves. There are two ways in which valves are worked by the steam-engine itself. The first of these is by the agency of some part of the engine that happens to move up and down, or perform a reciprocating motion, and the other is by the agency of some part of the engine which revolves. The following is a simple method, which we have seen applied to the short D slide, already described. In figure 95, A B P is the cylinder, P the piston, acting on the end L, of a great lever $L L^2$, raising and depressing it alternately, while the other end L^2 , united by a connecting rod $L^2 R$ to the handle or crank of a large wheel, turns it round. The manner in which the steam-valves are moved is by the long vertical bar T T, suspended from the lever $L L^2$, so as to move up and down with it. This bar T T carries two projecting plugs of wood $s s^2$ upon it, which strike alternately up and down the handle $l l^2$ at the bottom and top of the stroke, and so produce the reciprocating motion of the slide valve D, and by admitting the steam on alternate sides of the piston, and discharging it at the opposite ports, pro-

Fig. 94.

Steam-Engine.
Valve gear.

duce the continuous motion of the engine. In the figure, the steam is represented in the act of forcing down the

Fig. 95.



piston; but when the piston gets near the bottom, the plug s will have come in contact with the valve-rod $l l^2$, and will have forced it and the slide valve D into the opposite position, and so permitted the steam, formerly above the piston, to pass into the open air, while the steam on the

Steam-Engine. other side presses up the piston, so as to bring the plug s^2 , in contact with the lever, pressing it up, and the valve D down into its first position, and so on alternately.

Valve apparatus. This first plan of moving the valves by means of a plug-frame, rising and falling with the alternate strokes of the

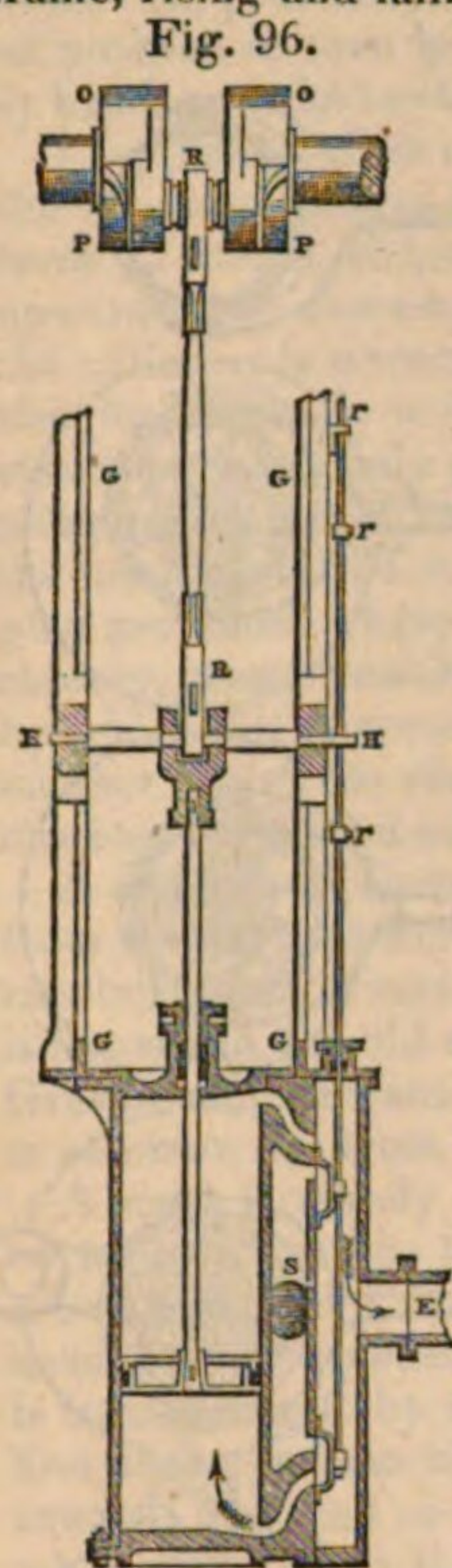


Fig. 96.

piston, has been principally adopted for pumping engines that have no revolving motion. We have, however, seen it adopted with advantage even in marine engines. It is noisy, as the sudden strokes of the prime mover produce an instant jerk, but it is effective, in so far as it at once opens the ports to their fullest extent, and so allows full effect to the entering steam, and full clearance to that escaping. The form in which we have seen it adopted in marine engines is as follows. The piston was kept in its true position by moving along two guide bars G G, on which it rested, through a cross bar H H; O P and O P are the cranks of the revolving axis; R R is a rod connecting the piston-rod with the ends of the cranks which it turns round. The valve-rod $r r$ is extended upwards as far as the piston-rod works, and two plugs $r r$ are so placed by adjusting screws, as to admit of the rod being raised and depressed at the proper moment by a projecting part of the cross-bar H, at the end of each upward and downward stroke.

A very beautiful method of working the valves of the steam-engine has been recently invented by Mr. Melling, the superintendent of locomotive engines on the Liverpool and Manchester railway, and applied with perfect success. It consists in deriving the motion of the valves neither from the rectilineal nor the circular motions of the machine, but from the connecting-rod, one end of which rod moves round in the circle of the crank, while the other end performs a rectilineal, or a circular reciprocating motion. Before entering on the consideration of this motion, it may be well to attend to the curve which a point in the connecting-rod describes.

Fig. 97.

The curve, Fig. 97, is manifestly a curve resembling the ellipse, although by no means a correct ellipse. It is an oval, one end of which is more oblate, and the other more elongated, depending on the length of the connecting-rod, and deviating more and more from a true ellipse, as the connecting-rod becomes shorter. In the centre of this oval, Mr. Melling places an axis, having a projecting arm, and in the connecting-rod there is placed a round projecting pin, which carries with it a radius arm from a fixed axis in the centre of the oval. This axis again carries another arm, or small crank, which is turned round with the axis, and is attached to the valve-rod, which it moves just as in the case of the eccentric. This motion has several good qualities. It is said to continue longer in perfectly good order than the common eccentric motion, and it is said to save steam. This last fact we are disposed to question. The motion exaggerates the properties of the eccentric.

One of the commonest of the many applications of the steam-engine is to produce the revolving motion of an

axle and wheel, and in the second system of valve apparatus, by which the steam-engine is rendered automatic, the reciprocating motion of the steam valves is derived from the continuous revolving motion of one of the shafts or wheels. Of the various methods in which this has been done, the following are some examples.

Fig. 98.

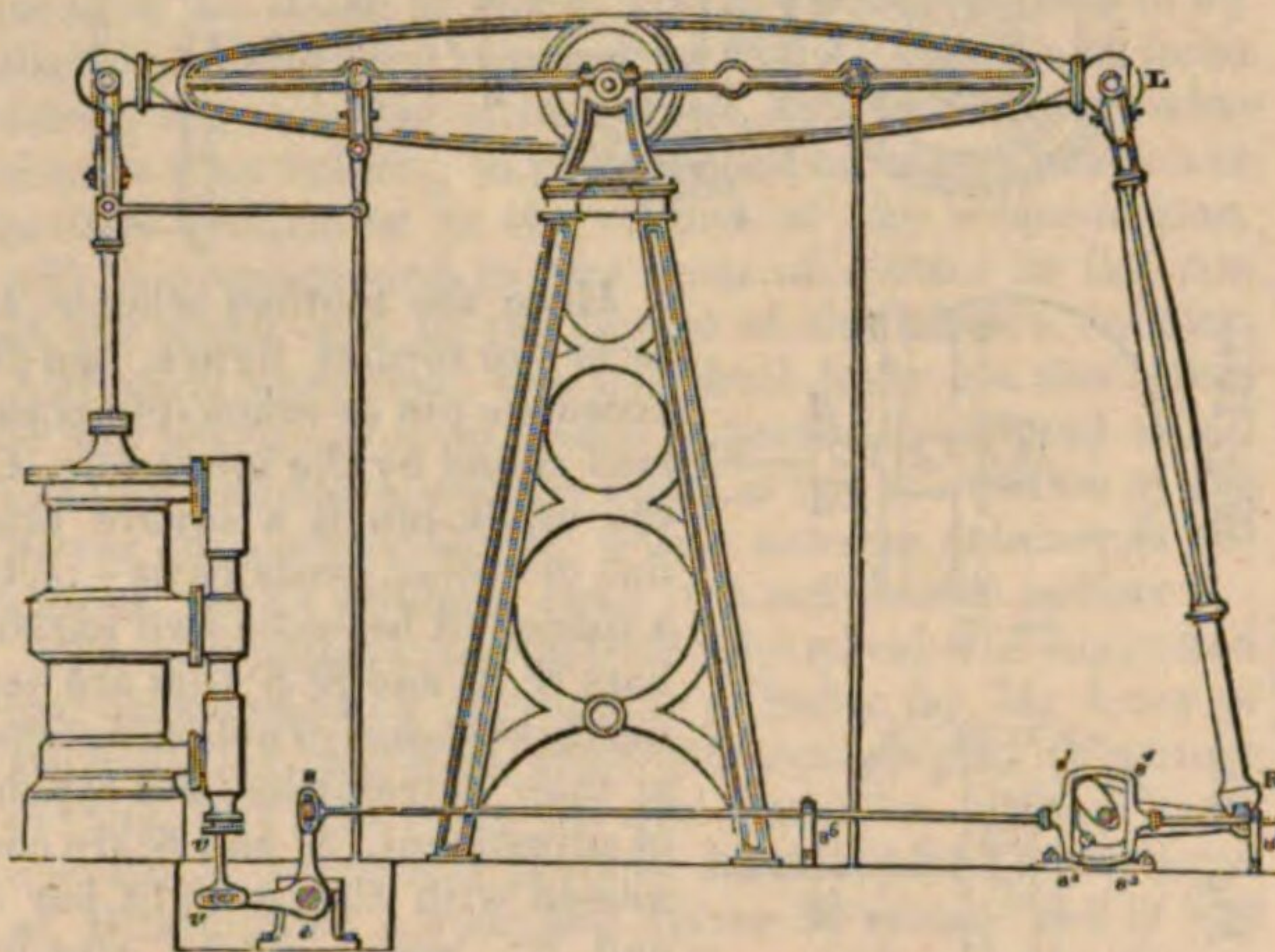
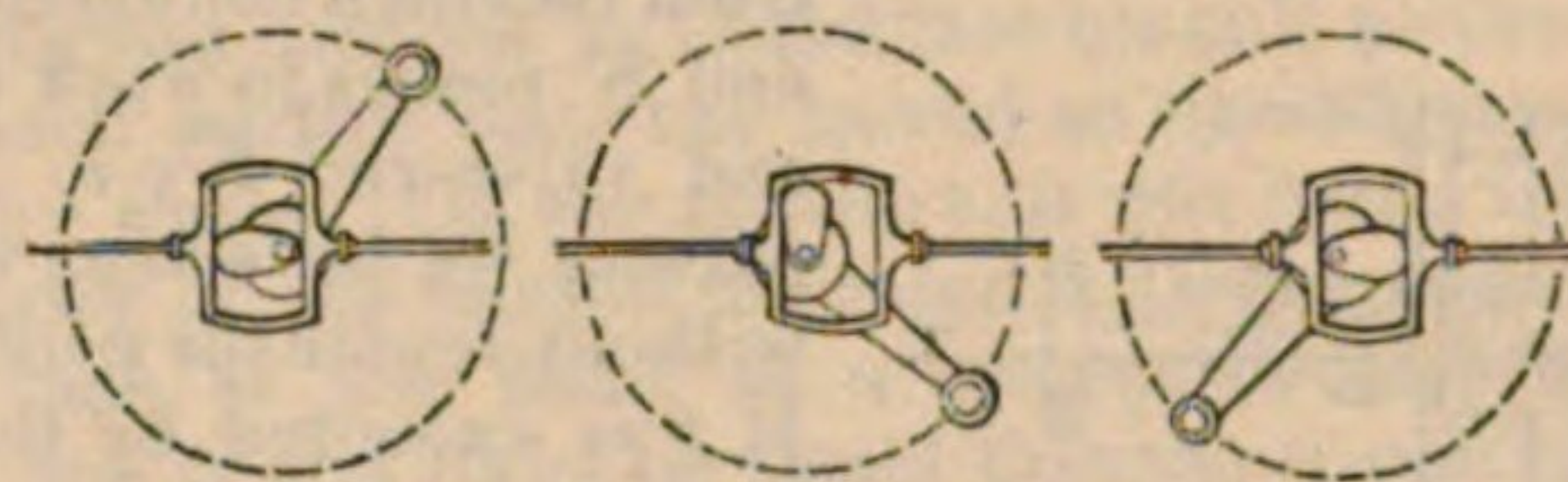


Fig. 99.

Fig. 100.

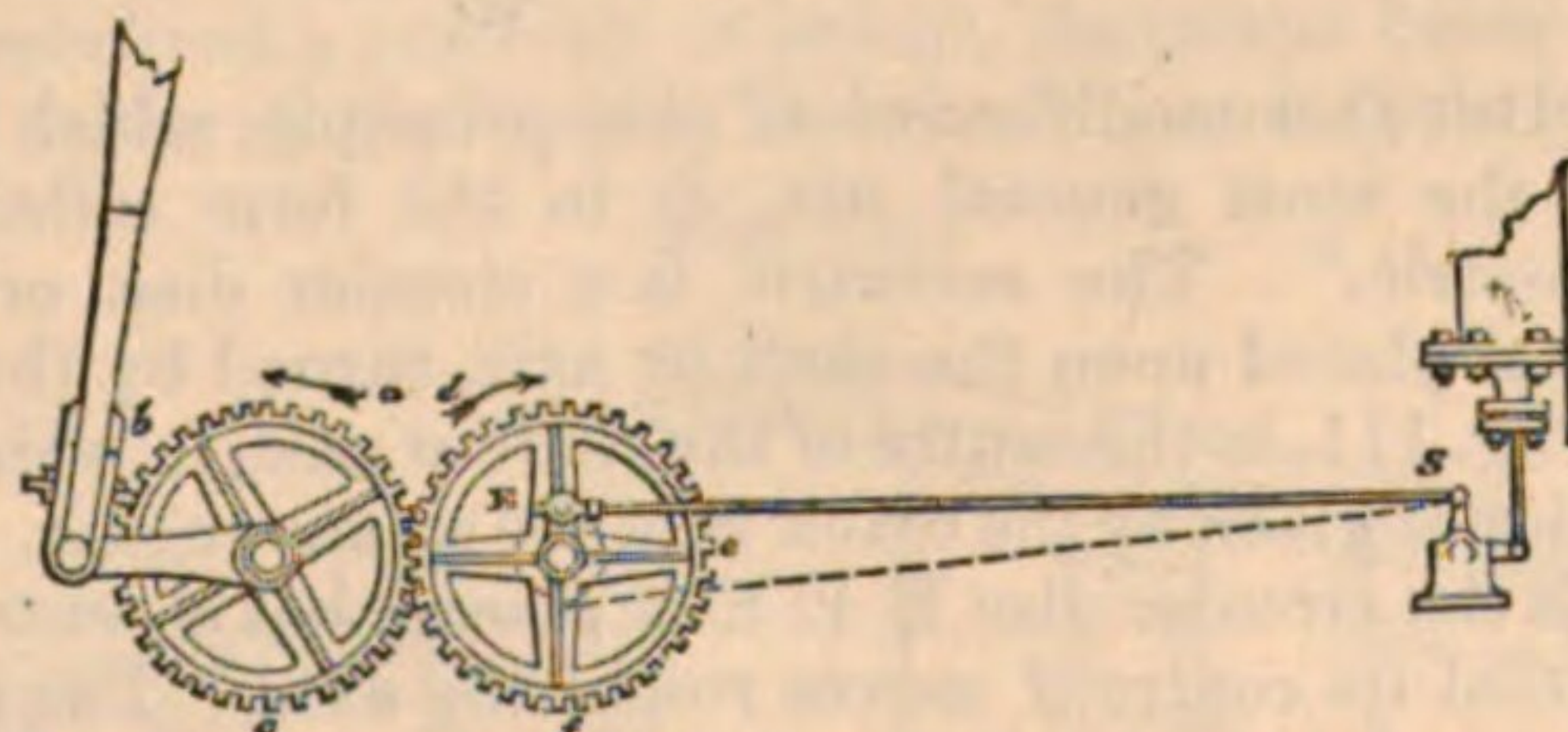
Fig. 101.



On the axis O, fig. 98, which is turned round by the rod LR so as to make one complete revolution during each alternate ascent and descent of the piston, and at the centre O, is placed a smaller axis, carrying round a cam or projection with it. A square frame $s^1 s^2 s^3 s^4$ encloses this cam. As the axis turns round, the cam comes into such positions as to bear upon the bars $s^1 s^2$ and $s^3 s^4$ successively, and so pushes the frame towards the right and left alternately. $se v$ is a small crank, to which the motion of the frame is applied so as to make it move round its centre e , and so to raise the point v , and the valve rod $v v$ up and down, giving the valve to which it is attached a reciprocating motion. The different positions into which the frame is forced by the cam are sketched in figs. 99, 100, 101.

Another form in which this motion has been given, is by connecting the large axle of the crank with a smaller one by toothed wheels, thus:—

Fig. 102.



The principal or crank axis carries round a wheel $a b c$ whose teeth give motion to the equal wheel $d e f$. The point E is out of the centre, and carries a small axis E, to which the crank is connected by the rod E s, so as to raise and depress the valve-rod. It is manifest, that during the revolution of the wheels $a b c$ and $d e f$, the point E will be carried round a circle, and communicate alternate motion to the rod E s, equal in extent to the diameter

Steam-Engine. of that circle. This circle must, therefore, be chosen of a diameter equal to the required motion or throw of the steam valves attached to the cylinder.

Valve apparatus. This motion has been modified into a very excellent and durable arrangement in the following form.

Fig. 103.

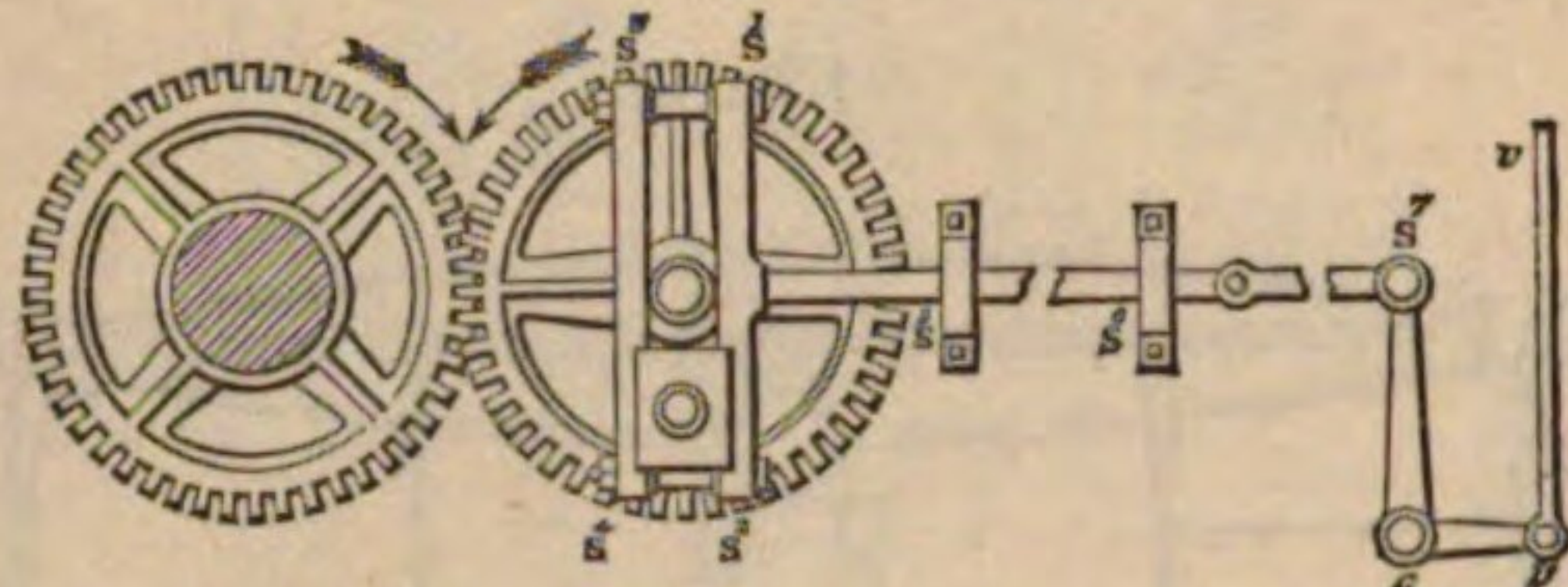


Fig. 104.

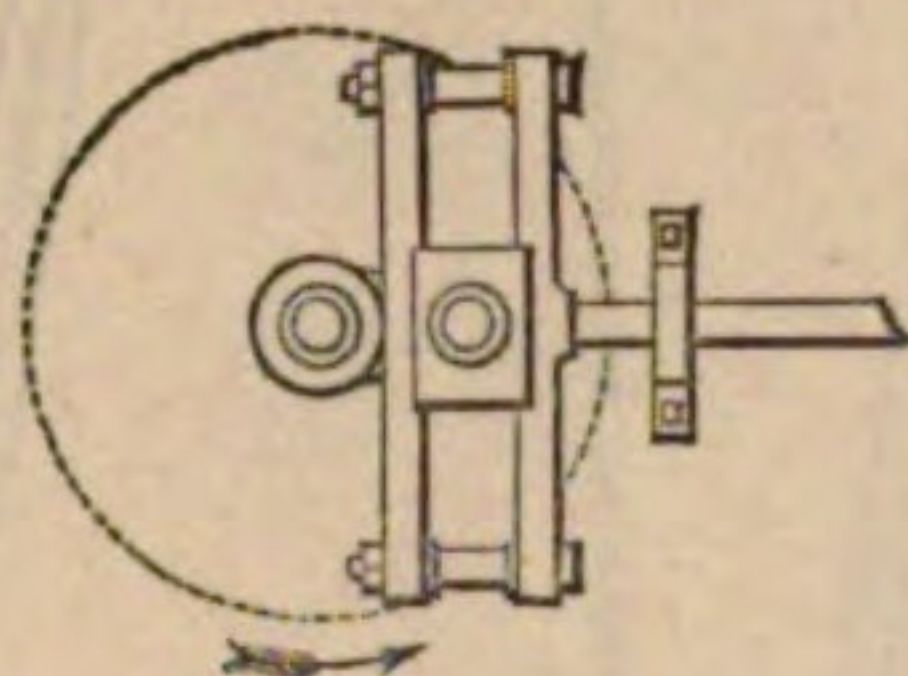


Fig. 105.

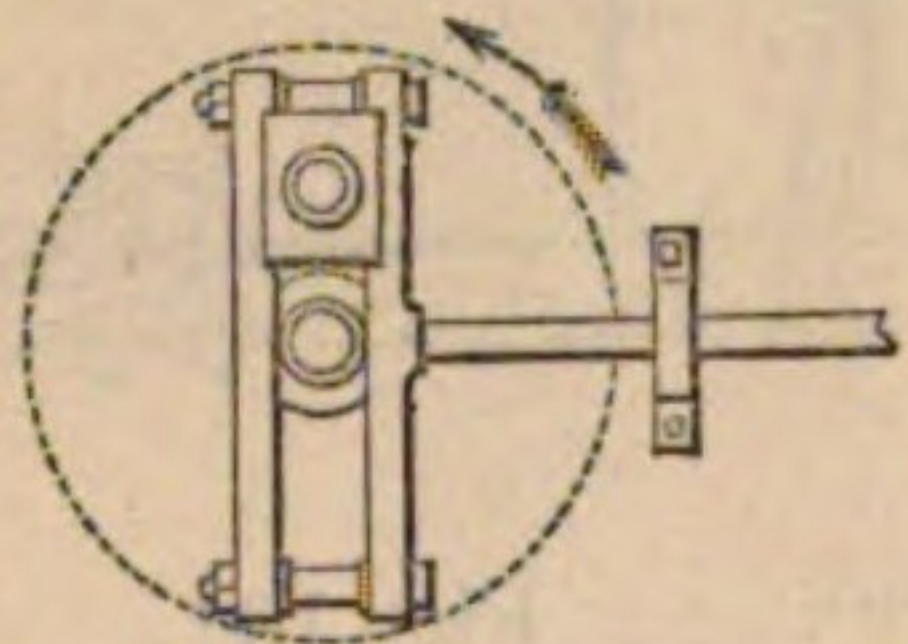
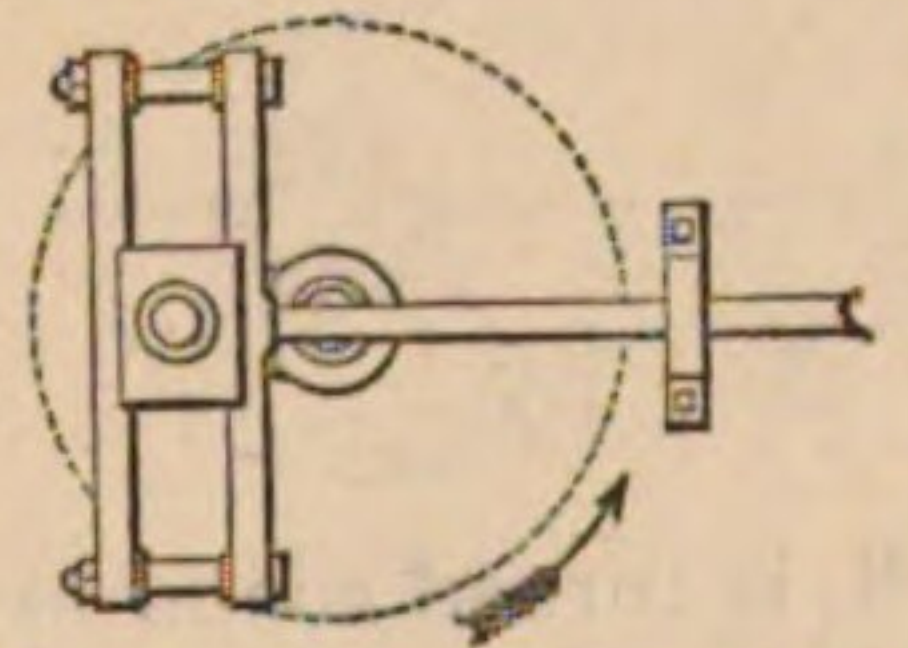


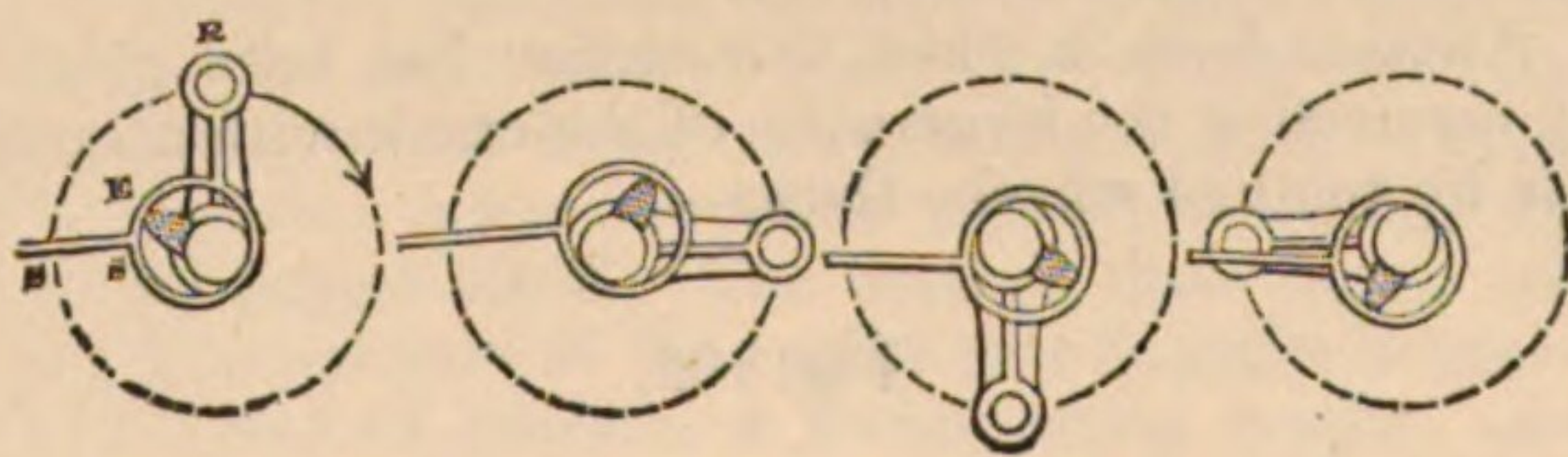
Fig. 106.



Here the toothed wheels are as in the former figure, and the eccentric pin or crank-pin is carried round by the inner one. On the crank-pin is a square brass nut or collar, made to fit exactly a space left between two parallel bars $S^1 S^2$ and $S^3 S^4$ that are kept *in situ* by means of nuts and screws at their extremities, and capable of adjustment. S^3 and S^4 are connected with the straight bar S^5 and S^6 , which works steadily through the collars S^5 and S^6 , and from its end a connecting link S^6 and S^7 passes to work the crank and valve-rod $S c v$. This apparatus we have seen work well without repair for a long period. It was executed by the Messrs Carmichael of Dundee. Figs. 104, 105, 106, show the apparatus in three other positions.

Another mode of producing the motion of the valves is by a projection in the great axis of the engine itself. A rigid circular hoop S encloses the axle as in figs. 107, 108, 109, 110. It is evident that if the projection E be just equal to the radius of the hoop the axle will revolve without producing motion in the hoop; but, if on the contrary, the axle and its projection be equal to the diameter of the hoop, as in the figs. 107, 108, 109, 110, it is apparent that the projection or cam, in passing round, must push the hoop in alternate directions.

Fig. 107. Fig. 108. Fig. 109. Fig. 110.



But that modification of this principle, which is in by far the most general use, is in the form called "the eccentric." The eccentric is a circular disc, or ring of metal placed upon the shaft or axis, turned by the crank. O , fig. 111, is the centre of the shaft or axis, to which revolution is given by the crank R of the steam-engine. On this axis the circular disc $E E E$ is placed, but eccentric to it, so that its centre d moves round the axis. The distance of the centre d of the disc from the centre O of the axis, is called the eccentricity, and it is equal to half the throw or range of the motion of the valves to be moved by the eccentric. The rod, fig. 112, is called the eccentric rod, and is attached to a hoop or circle that exactly fits the eccentric disc. The various positions which the eccentric will take during the revolution of the engine, is shown in the succeeding figures.

Fig. 111.

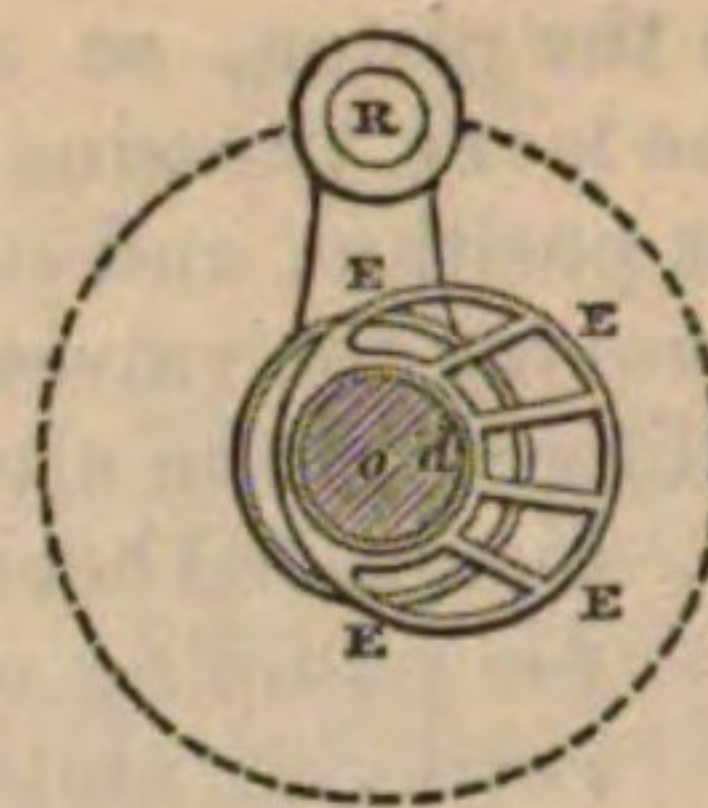


Fig. 112.

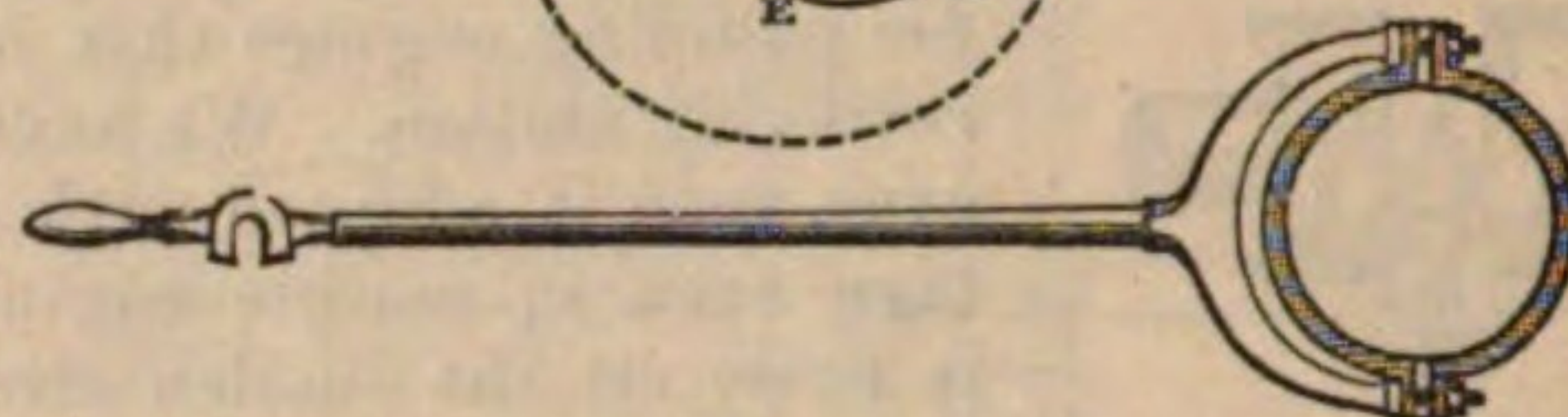


Fig. 113.

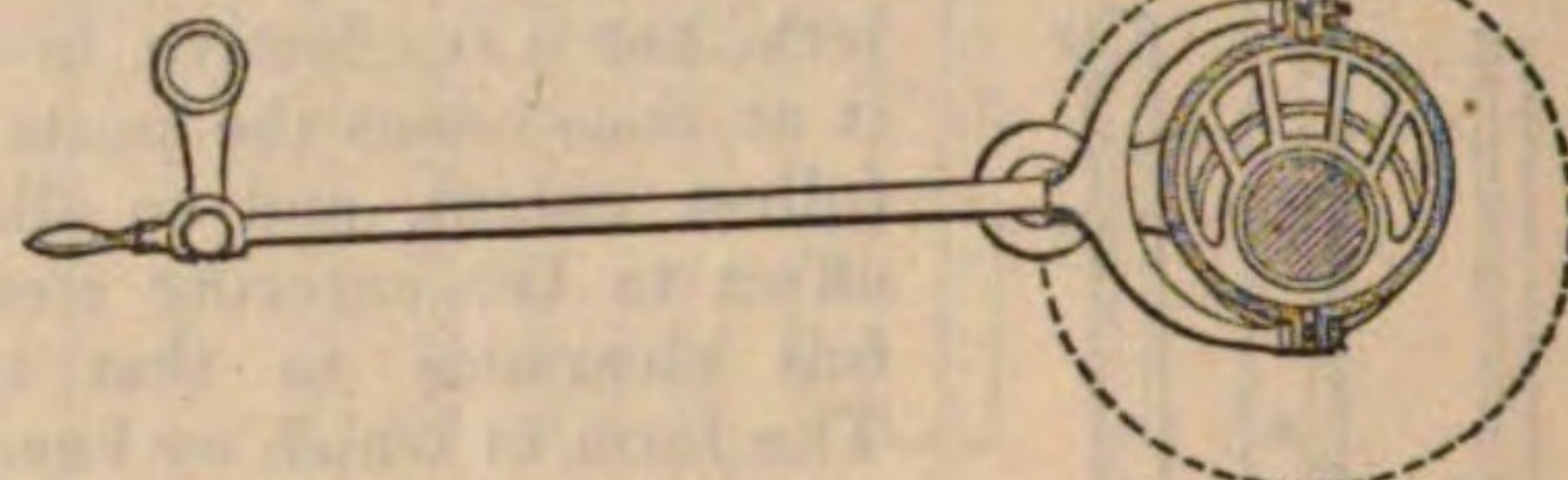


Fig. 114.

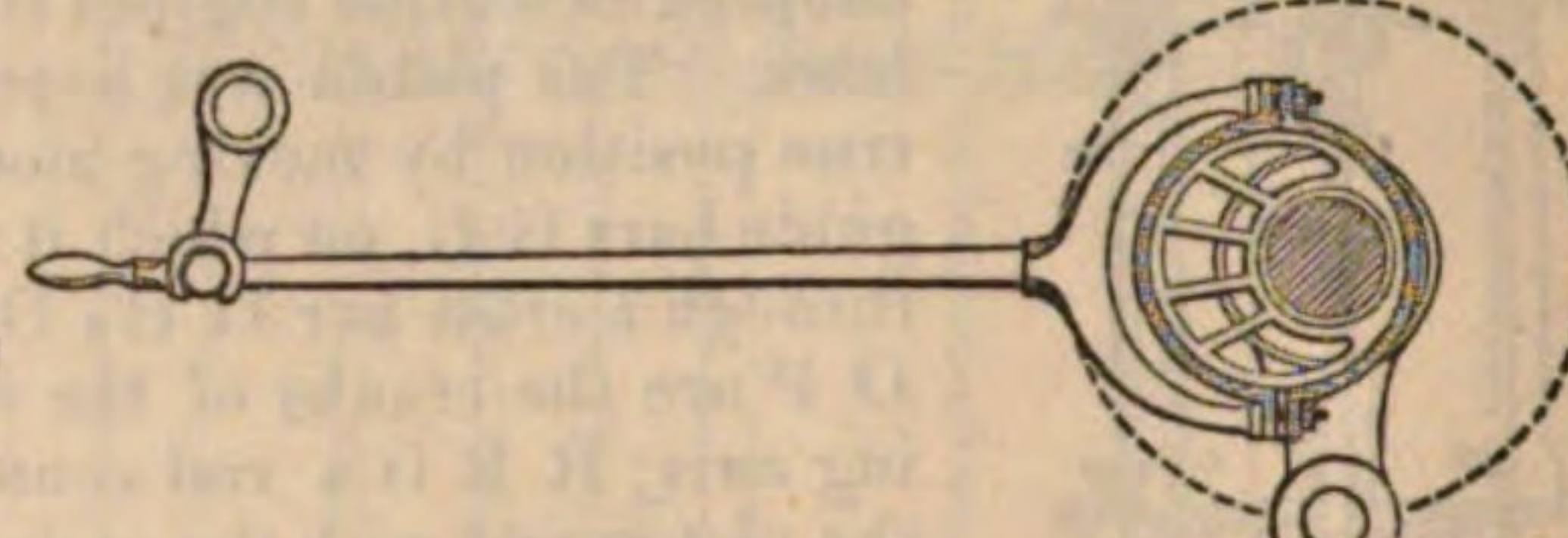


Fig. 115.

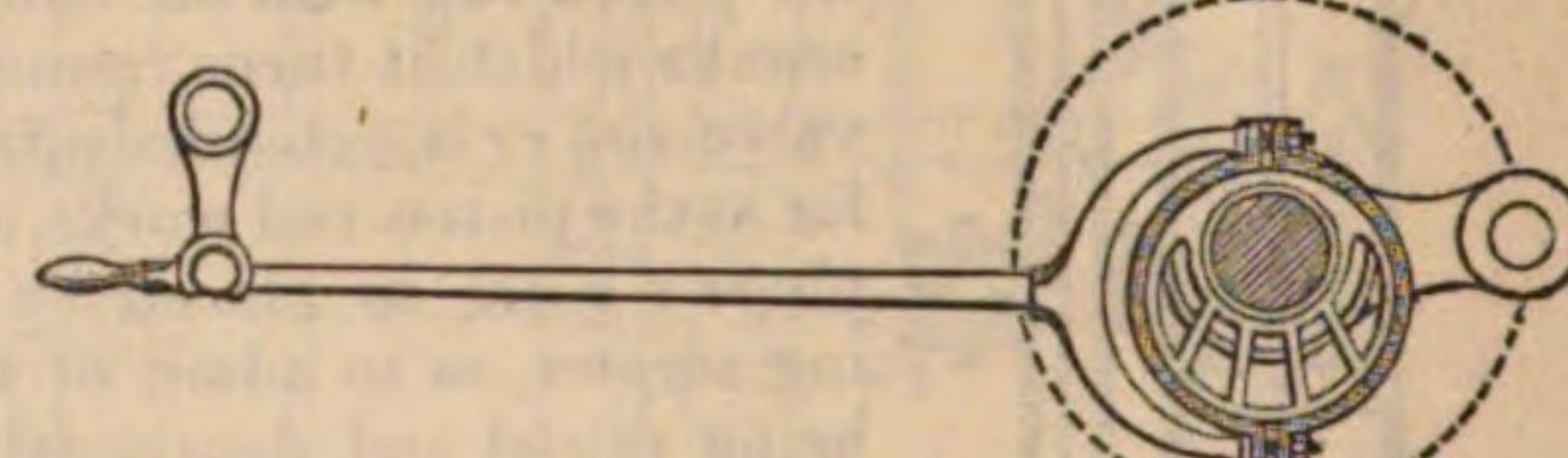
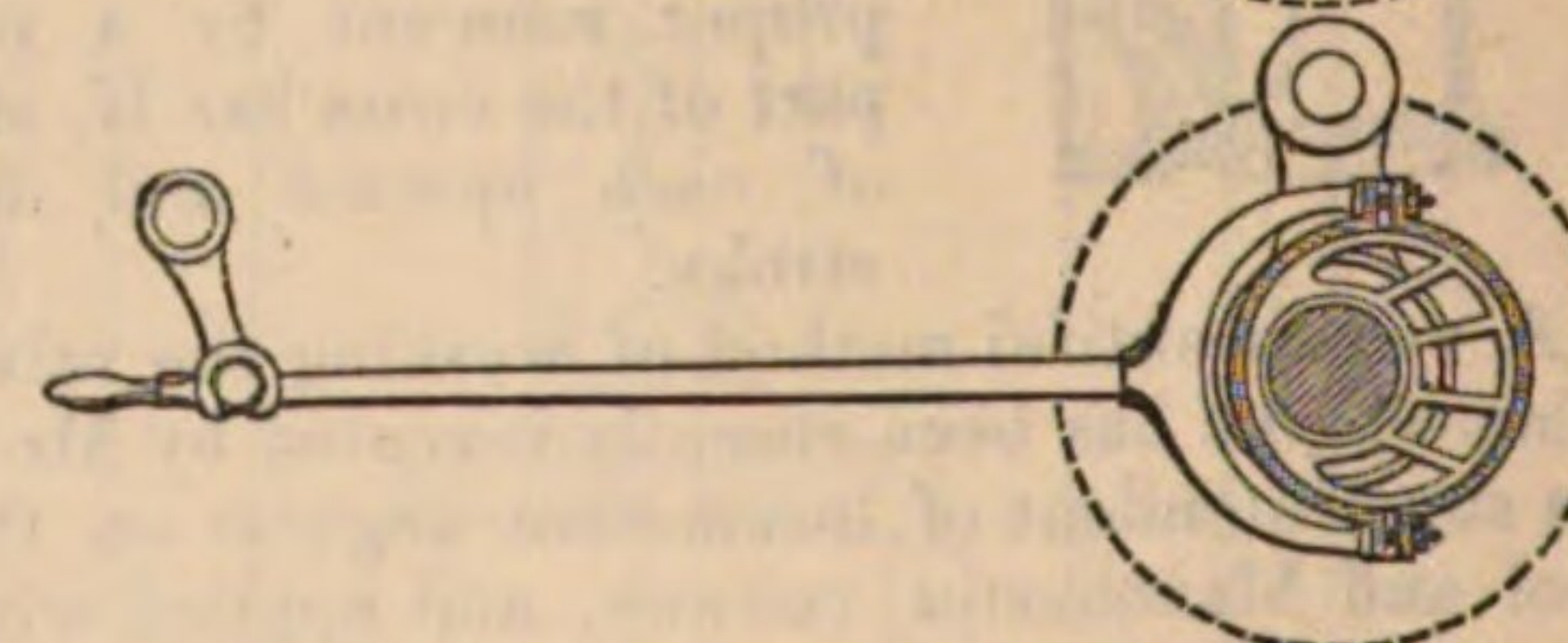


Fig. 116.



We have used the common eccentric in a much simpler form than that generally adopted, by placing it immediately over the valve which it moves. In engines which require compactness and simplicity, this way is useful, and is valuable where the axis of rotation is immediately over the valves, thus:—

Fig. 117.

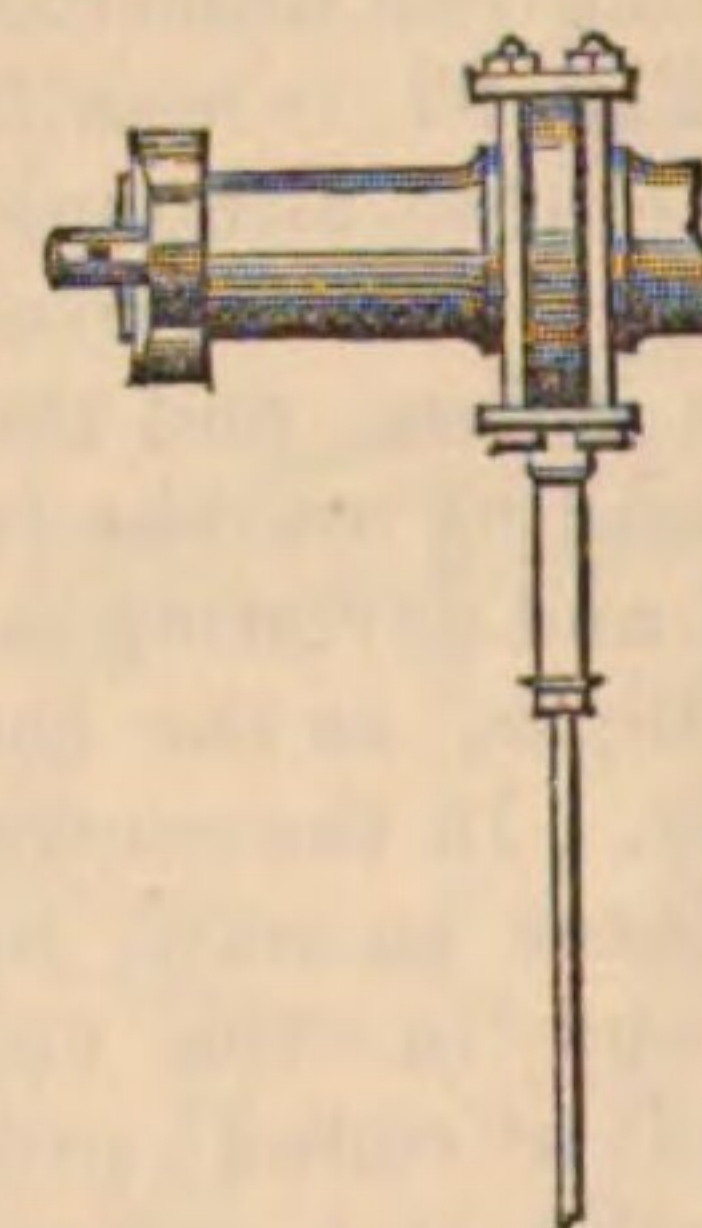
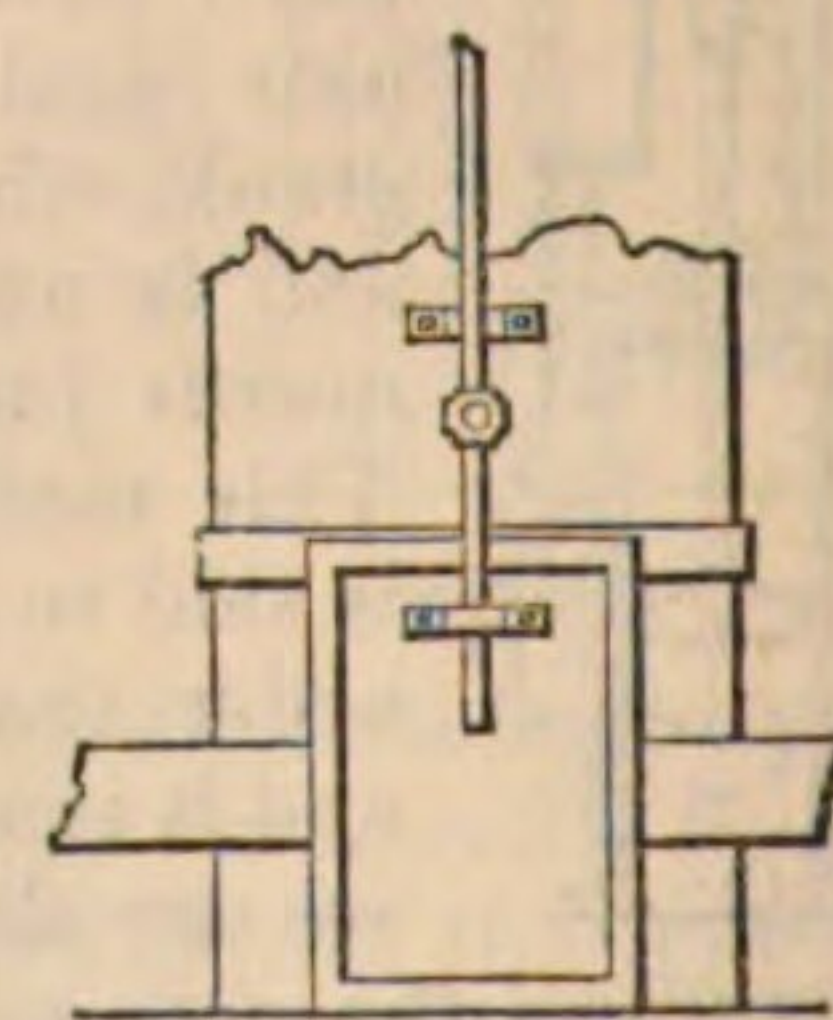
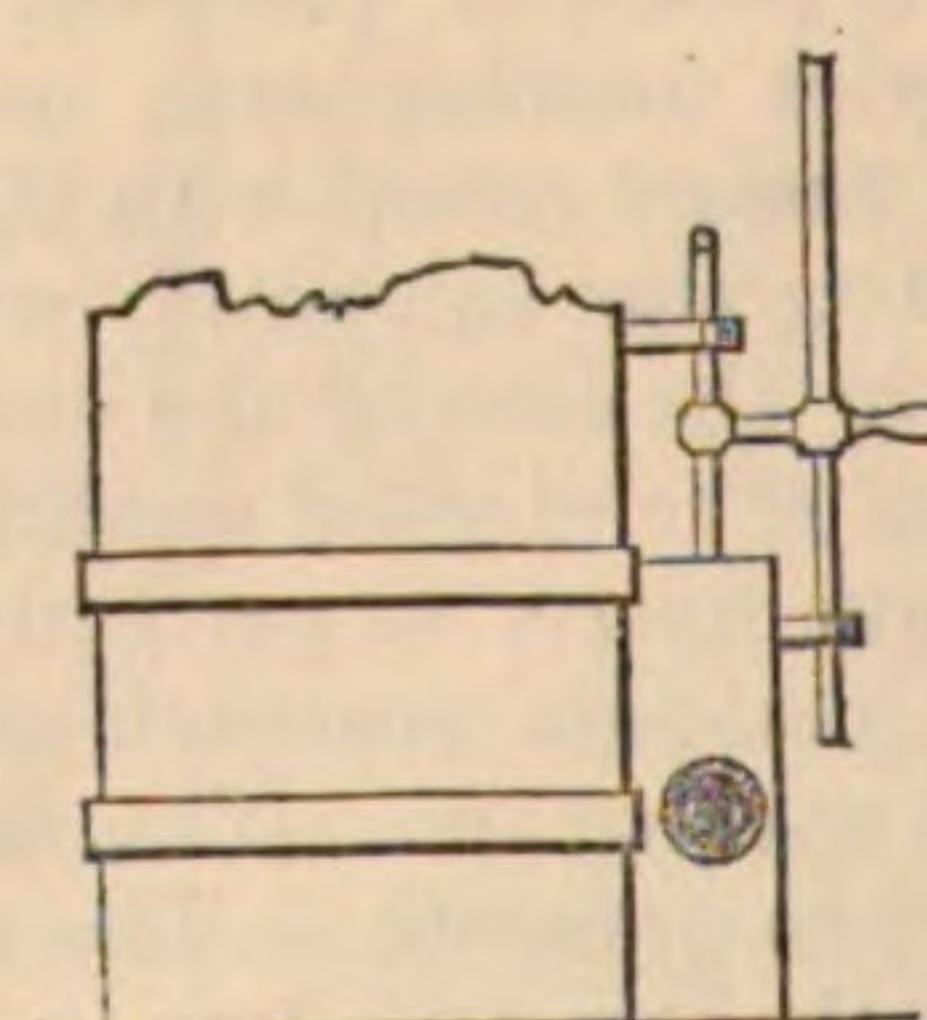
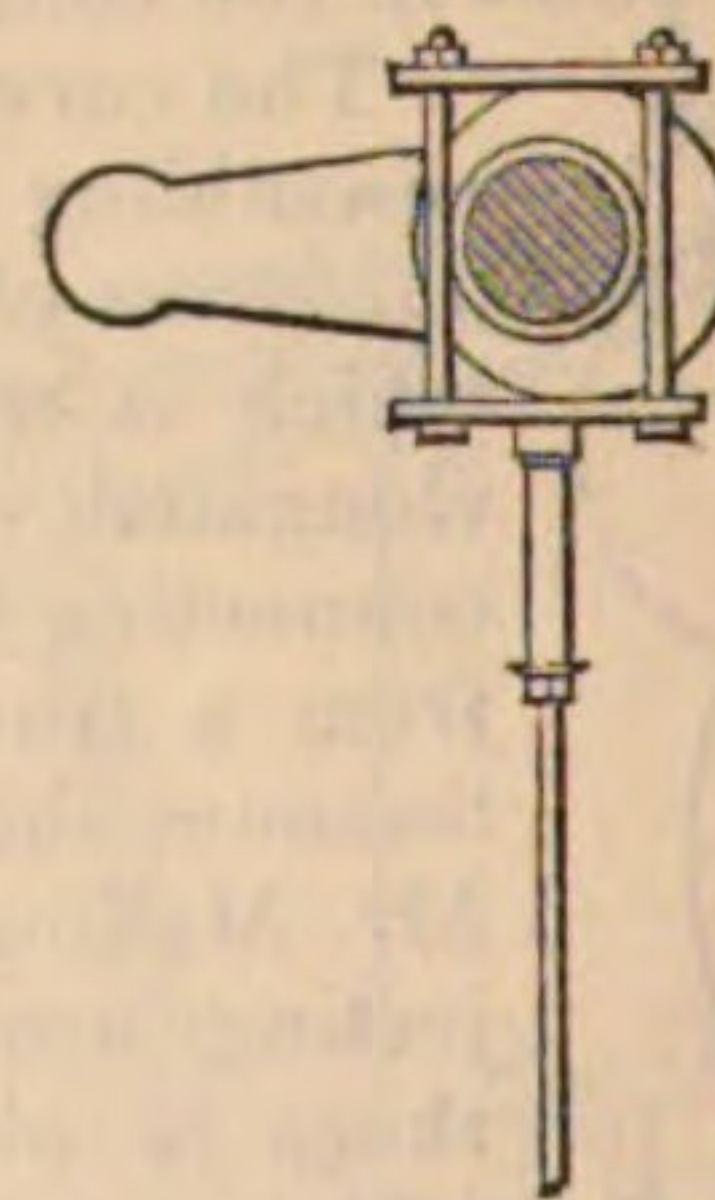


Fig. 118.



The valve-rod, figs. 117, 118., branches out into four portions; a flat brass plate is inserted at their separation, an-

Steam-Engine.
Valve apparatus.

other at the summit unites them. The eccentric disc works between the side forks of the rod, and bears against its top and bottom plates, as seen in fig. 117. The other forks of the rod are made, in width, equal to the diameter of the axle, which thus prevents the rod from deviating from the vertical position as seen in fig. 118; a handle is added to work by hand, and the reversing process is performed as usual.

The Crank.—One of the most important appendages of the steam-engine is the crank, by means of which the force of steam, although at first producing motion only upwards and downwards in the right line of the axis of the cylinder, is nevertheless rendered capable of exerting that force equally well in a circular direction. When the steam-engine is only employed for some such purpose as pumping up water, no crank is necessary, but as some of the most usual and valuable applications of the steam-engine are those where it turns wheels of mills, cotton machinery, steam-vessels, or locomotive engines, the crank, by which this is accomplished in an admirable and simple manner, which has superseded every other plan of transmission, is entitled to very minute consideration.

A crank is an elementary machine which has been used from the earliest times for the purpose of converting a revolving into a rectilinear motion, or the reverse. It is figured in the old machines of the Egyptians, Chinese, Greeks, and Romans, and in water machinery it has been in common use from the time of Ctesebius. Fig. 119.

A crank is merely a handle to a wheel, by which it may be turned round. Let a be an axis of a wheel $b c d$, $a R P$ the usual bent (or crooked) handle, by which it is turned round by the man, whose arm first pushes it from him, and then draws it towards him, and so continually turns the wheel round, then the part $a R$ radiating from the centre, is called the crank, the axis $a x$ is called the crank-axle, and the straight part PR is called the crank-pin.

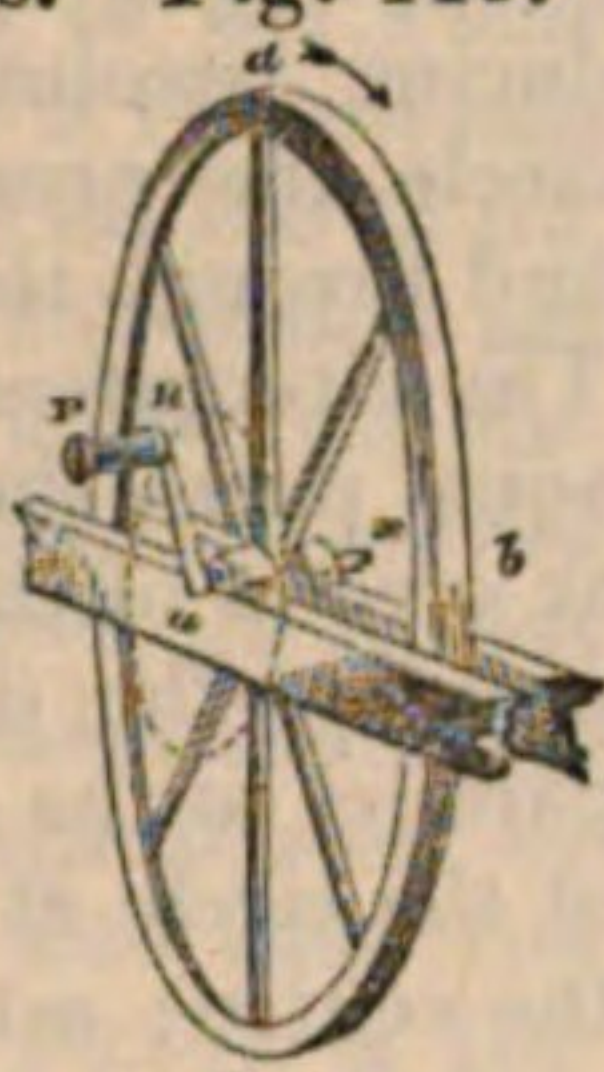
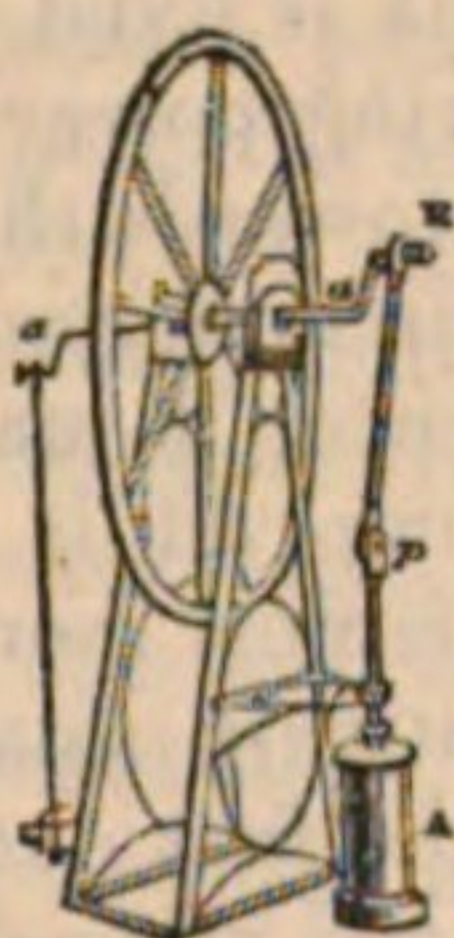


Fig. 120.



Now imagine, instead of a man's arm, a rigid metallic connecting-rod, and instead of the strength of his body, conceive the force of steam to be applied through a cylinder piston and piston-rod to the crank by means of the connecting-rod, and the steam will produce the revolution of the wheel by means of the crank, axle, and pin, as in the figure, A the cylinder, p the piston-rod, $p R$ the connecting-rod, R the crank, and $a x$ the axis.

Action of the Crank and Fly-wheel.

On examining, in detail, the action of the crank, it is to be observed that the force exerted by the steam is neither continuous in direction nor in action. If the steam be admitted first below the piston, it forces it to the top of the cylinder; it is then cut off preparatory to its being admitted above the piston; and in the interval it has no motive action. When admitted above the piston, it forces it to the bottom of the cylinder; and again there is a cessation in its action during the change in the position of the valve. Now it is evident that this recurring cessation of action between the alternating impulses, would prevent the production of continuous revolution in the wheel, but for the power of the wheel itself of continuing the motion, by what is termed the momentum of its mass. When the steam, during a stroke of the machine, is acting most powerfully on the piston, part of its power is absorbed in giving motion to the wheel; and when, at the end of the stroke, it ceases for a time to act, the wheel gives out the power which it had absorbed, and continues its motion until the next stroke gives it a fresh accession of power. A wheel of this kind, when attached to an axle for the purpose of equalizing motion, is termed a fly-wheel; and to obtain the full benefit of its equalizing

power, it is made of large diameter, that its rim may move rapidly, and it is made of great weight, being formed either of lead or iron, that it may acquire momentum to render the motion as uniform as possible.

Still, however, it must be remembered, that the equalization of the motion produced by the fly-wheel is partial, not perfect. Matter only takes up or gives out force when it changes from one velocity to a different one. If, therefore, the fly-wheel take up into itself the accession of force of the steam at one part of the stroke, it does so by slightly accelerating its motion; and if it give out force during the cessation of the stroke, it is by slightly reducing its own velocity in so doing. The approximation to perfect uniformity in the motion of the steam-engine, will be proportioned to the mass of matter in the rim of the wheel and to the square of the wheel's velocity. Although, therefore, the fly-wheel improves the action of the crank, so as to make it perfectly adapted to all ordinary purposes, still the effect is not so equable as the power of a water-wheel, where *extreme* delicacy is required. In all ordinary cases it is sufficiently uniform.

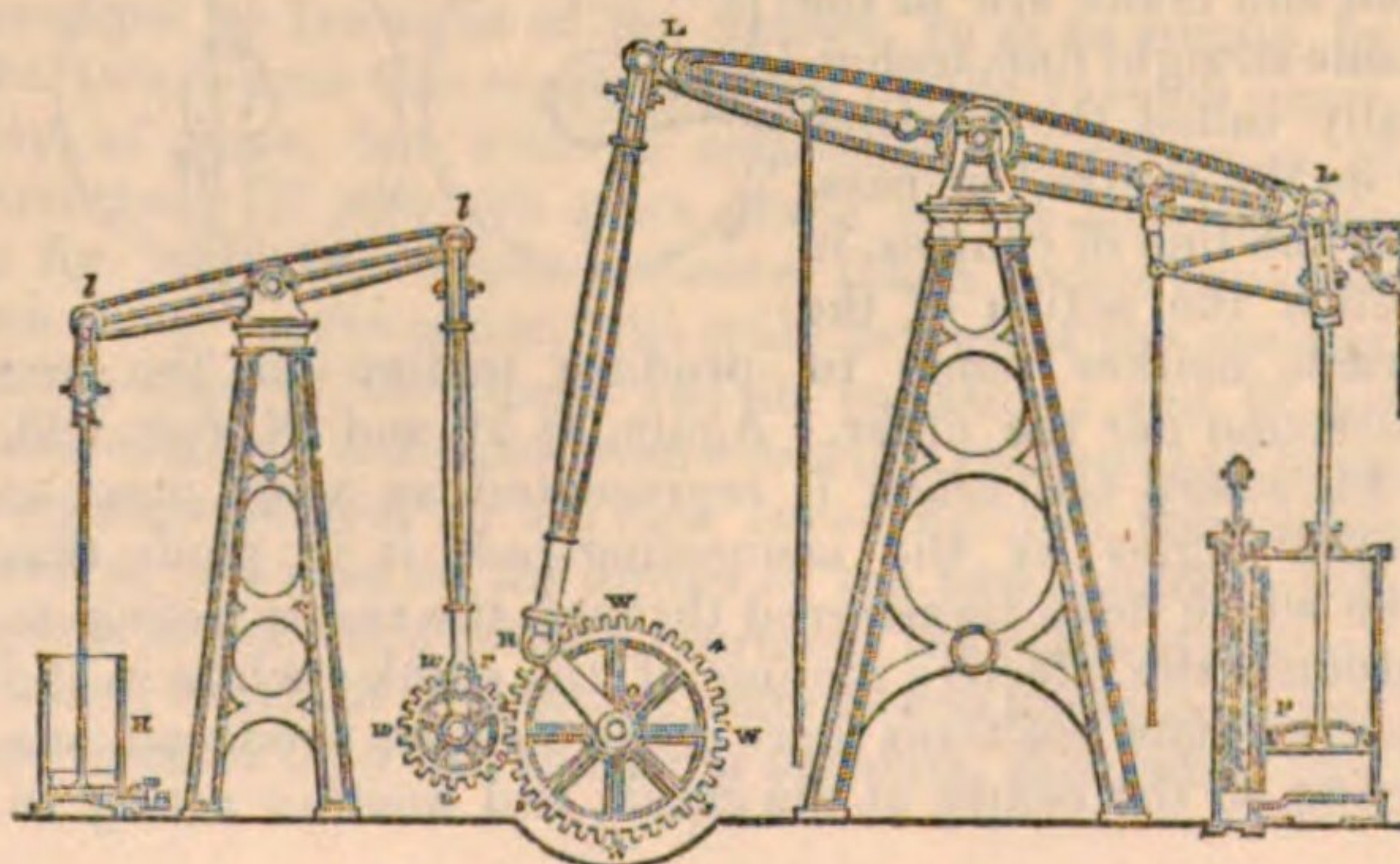
The following substitute for a fly-wheel was suggested and constructed by Mr Buckle of Soho, for Mr Lucy of Birmingham, and is an admirable and elegant substitute or auxiliary; so as to be, for even the most delicate operations, practically perfect. Mr Lucy had constructed at Birmingham a flour mill driven by steam; and it had been his object to obtain perfection without any limitation of expense. He had got one of Bolton and Watt's best steam-engines, and yet he found that his mill neither produced such perfect flour nor moved so smoothly as mills driven by water. On the contrary, it was found that the irregularity of the motion produced a larger quantity of coarse than of fine flour, at a mercantile loss to the owner; and it was likewise found that the irregular propulsion *a tergo* interfering with the uniform motion, towards which the millstones tended by their own momentum, produced a clanging reciprocation along the whole line of toothed gearing, which was most injurious, and rapidly destructive to the toothed wheels. When we visited the spot in 1838, the ruins of former wheels, most unequally worn and totally destroyed, were strewed about the yard. The usual plan of increasing the weight of the fly-wheel was resorted to without success; and Mr Lucy applied to Mr Buckle to propose a remedy for the evil. This remedy Mr Buckle found in the very simple contrivance of a pneumatic pump. In the mint at Soho a pneumatic pump had been introduced by Mr Watt, for the purpose of producing a reaction, on the principle of the experiments of Otto Guericke, which we have already described. The force of the steam-engine was made to draw up a piston from the bottom of a cylinder, leaving a vacuum below it. Into this vacuum the piston was again carried down, after the action of the steam had ceased, by the whole force of the atmosphere, amounting to about 15 lbs. on every inch of its surface. Thus the atmosphere was rendered a reservoir of power, the power being first of all taken up by forming the vacuum, and again given

Steam-Engine.

Equalization by the Fly-wheel not perfect.

Mr Buckle's Pneumatic Equalizer.

Fig. 121.



Steam-Engine.
Mr Buckle's Pneumatic Equalizer.

out by the atmosphere pressing the piston down into the vacuum.

The following is the arrangement by which Mr Buckle accomplished the object which he had in view. P, fig. 121, being the usual piston and cylinder of the steam-engine, L the usual lever, L R the connecting rod, R O the crank, and R W W W a toothed wheel carried round by the crank, as usual in the steam-engine: there is added *r w w* a smaller wheel of half the number of the teeth of the other, so that during a semi-revolution of the small wheel, the large one performs a quarter of a revolution; *l l* is a second lever to which there is attached a piston-rod L H, carrying a piston from top to bottom of an open cylinder H. When the piston is at the bottom of the cylinder H, the crank R is near the point 1 in the figure. While the crank passes from 1 to 2, it is raising the piston in the pump, and against the pressure of the atmosphere, the steam exerting its greatest force; but when the crank reaches point 2, the little wheel *r w w* is at the bottom of its circuit, the piston in the pump is at the top; and now the pressure of the atmosphere carries the piston down into H, turning the little wheel *r w w* along with it, and propelling the large wheel and crank from 2 to 3, through that part of the stroke where there is a cessation of the action of the steam: then again from 3 to 4 the excess of the power of the steam is employed in raising the pump piston; while from 4 to 1 the piston of the pump, carried down by atmospheric pressure, brings round the mechanism once more to the point 1.

So perfect was the action of this mechanism that the fly-wheel had been wholly removed, and the engine and the whole mill-work were moving in the most smooth and effective manner. It was found that the change enabled them to give all the grinding stones a greater velocity than formerly, so that the quantity ground was greater, in the proportion of 56 to 52, and the quantity of the finest or first flour, from the same wheat was likewise much increased; so that, both by quantity and quality, the owner of that mill was now able to "command the market." The same motion has subsequently been applied to cotton-mills with perfect success; the quality and the quantity of yarn produced being much improved.

Analysis of the action of the Crank.

From the circumstance already noticed, that at one point the steam possesses no power of giving revolution to the crank, it has been imagined that some considerable loss of the power of the steam takes place during the transmission of its moving force through the crank. This is a grave error, and it has produced other errors, which we shall consider in our chapter on rotatory steam-engines.

Figs. 122 to 125 represent the crank in different positions. In figs. 122, 125 the connecting-rod and crank are in the same straight line, technically called the position "on the centre," or passing the line of centres, in which the action of the crank neither tends to produce motion in the one direction nor the other. Again, at M and N, figs. 123, 124, where the crank is represented as acted upon at right angles by the connecting-rod, it is plain that the whole force transferred through the rod is acting to produce the effective motion of the crank; while in the intermediate positions there are two effects produced, one acting on the centre of the crank, and another acting to

give it revolution. For the purpose of examining the proportion of these forces to each other, we may use the two following diagrams:

Steam-Engine.
Analysis of the Crank's action.

Figs. 126, 127.

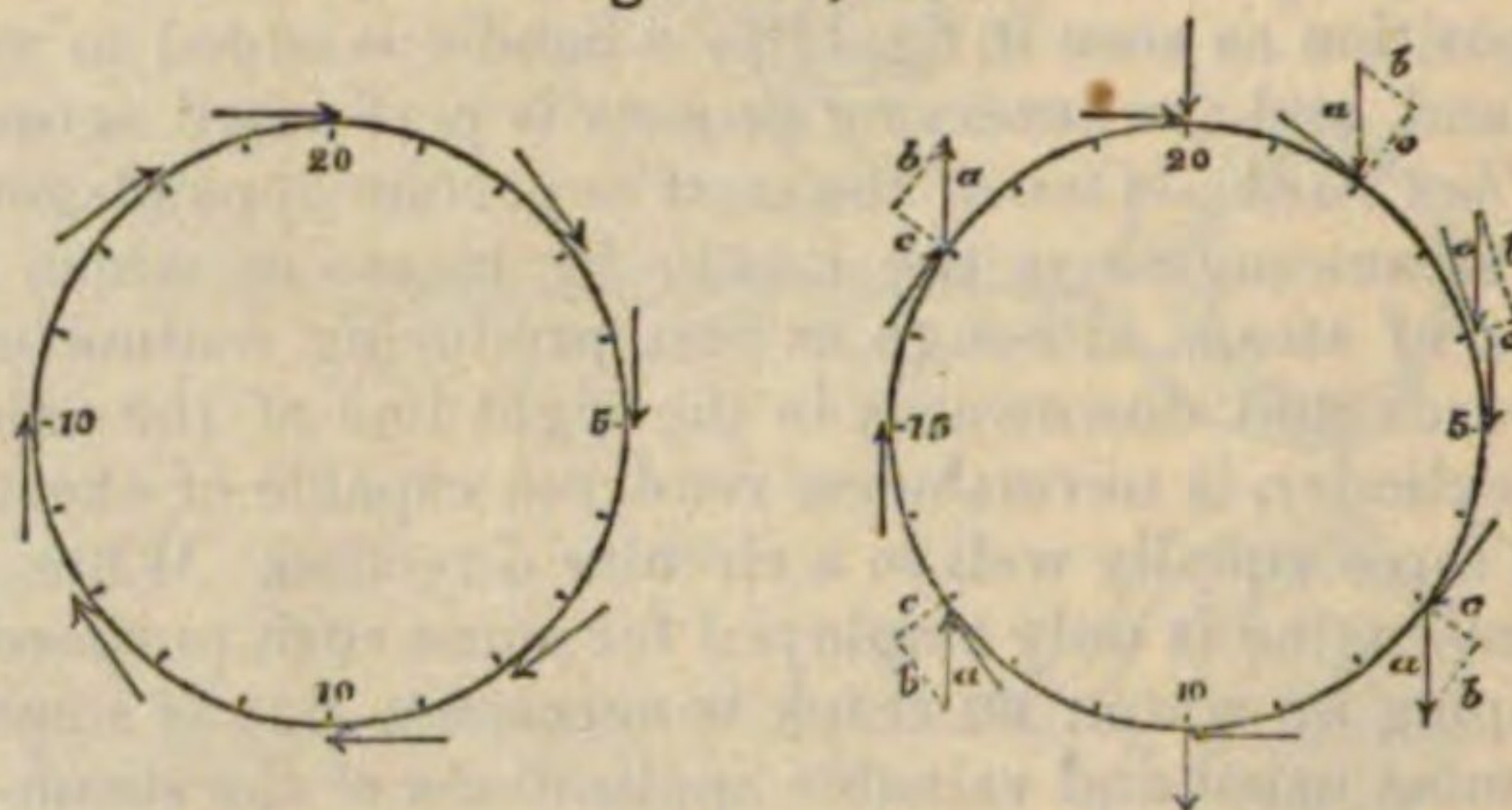


Fig. 126 represents the circle of the crank, the arrows showing the direction in which the crank-rod would require to act, in order that all its force should be undivided, and produce alone the single effect of causing revolution. Fig. 127 indicates the deviation which the actual motion of the crank exhibits from this hypothetical condition. The arrow *a* indicates the direction of the action of the connecting-rod, which at divisions 10 and 20 is acting only towards the centre of the circle with no effect in producing revolution. At divisions 5 and 15, the whole effect takes place in producing revolution only. Through the first half of the circle the pressure of the rod acts wholly downwards, and through the latter half of the stroke wholly upwards. The circumference of the circle being divided into 20 equal parts, the analysis of the force is given in the figure at several of these points. At the second division, *a* represents the direction of action of the crank-rod, *b* is parallel to the direction of the circumference (or tangent) of the circle at that point, while the line *c* is directed to the centre; *a* indicating the direction of the whole force of the connecting-rod, *b* representing the effect produced in the direction of the tangent to turn it round, and *c* the effect of the force of the connecting-rod acting to produce pressure on the centre of the crank; but as the centre of the crank is fixed and prevented from moving, none of the moving power of the crank is given out in producing motion towards the centre, but only in producing motion in the circumference. At the fourth division of the circumference, it may be observed, that the effect of the connecting-rod is differently distributed. The whole force *a* is now more nearly in the direction of *b*, and *c* is comparatively small; showing that as we approach the end of the first quarter revolution, the force of the connecting-rod is producing much less pressure in the centre of the crank, and pressing in a higher proportion in the direction of the revolving effect, until at last the connecting-rod being at right angles to the crank, its whole pressure acting to turn round the crank, none of it is directed towards the centre. After passing the quadrant point 5, the crank-rod still presses downwards, as shown by the arrow *a* at point 7; but, at its two effective pressures, one represented by *b* still acts in turning round the crank, while another represented by *c*, instead of acting towards the centre, as in the upper quadrant, now produces a pressure which would draw the crank away from the centre; but as the crank is fixed, none of the motive power is employed in producing any motion of the crank away from its centre. Similar alternating effects are produced through the other quadrants; so that, while the pressure of the steam, acting through the connecting-rod upon the extremity of the crank, is divided into two effects, one of these is prevented from expending the moving force of the engine by the fixedness of the crank centre, and the whole motive power is given out only at the circumference of the crank circle in turning it round, but in a proportion of pressure

Steam-Engine.
Analysis of the Crank's action.

that is continually varying from 0 to a maximum, and from a maximum to 0, through every successive quadrant of the circle. The amount of the variation is shown in the following table:—

Points in the figure.	Pressure in direction of revolution.
0 and at 20	0.00
1 19	30.90
2 18	58.78
3 17	80.90
4 16	95.11
5 15	100.00
6 14	95.11
7 13	80.90
8 12	58.78
9 11	30.90
10 10	0.00

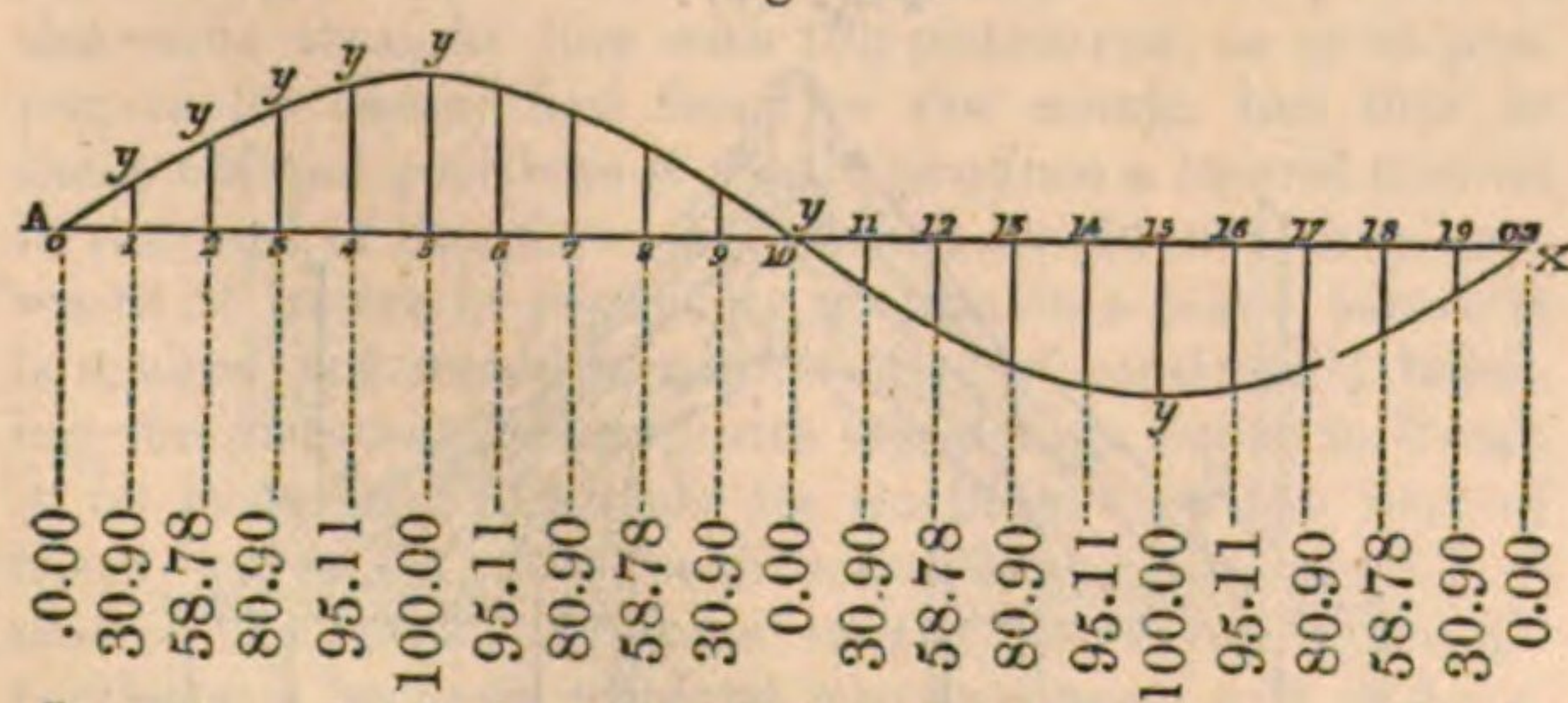
Mean pressure 63.11

The mean pressure on the crank being in the table about 63 pounds, taken on an average of the whole circumference of the circle, the pressure varies from 36 pounds above the mean, to 63 pounds below it. The total pressure of the steam in the cylinder, forces the connecting-rod up and down through a space equal, each time, to the diameter of the circle, while the connecting-rod carries the crank through a space which is equal to the whole circumference; and as the circumference of a circle bears to twice its diameter an approximate ratio of 100 to 63, it follows, that the pressures on the crank and piston are inversely as the spaces through which they move; the motive power of steam in the cylinder being 100 lbs. moved through a space of 63, and the motive power given out in the crank, being a mean of about 63 lbs. moved through the circumference of a circle which is represented by 100, so that the motive power is in the one case 100 lbs. $\times$ 63 = 6300 lbs., and in the other case 63 lbs. $\times$ 100 = 6300 lbs.

The crank is merely one beautiful exemplification of the great dynamical principle, which includes in it the law of operation of all the elements of machinery, "that in uniform motions the quantities of motive power, or *vis viva*, may be transferred from one point to another, through every variety of direction, velocity, and intensity, by material mechanism, without being thereby altered in quantity, except in so far as friction and imperfect rigidity may diminish its amount by a certain percentage, which diminution it is the aim of all perfect construction and design, in the practical application of machinery, to reduce to the smallest possible amount." To render uniform the effective pressure given out by the crank, is the object of the fly-wheel, and of the pneumatic pump of Mr Buckle. For the same purpose many other expedients have been devised; and the following explanation is intended to facilitate the comprehension of the nature and value of these expedients.

The variation of pressure on the crank of a steam-engine, may be conveniently represented by curves.

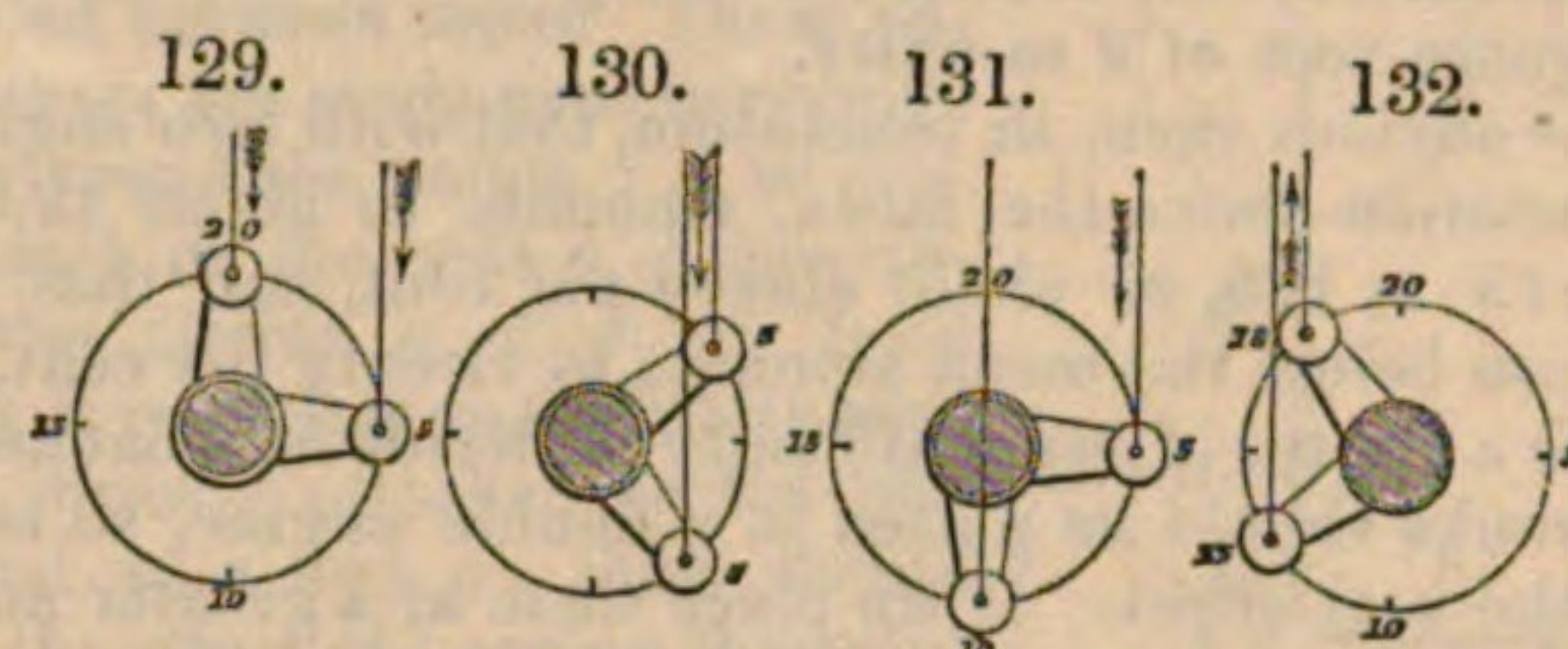
Fig. 128.



Let the circumference of the circle described by the

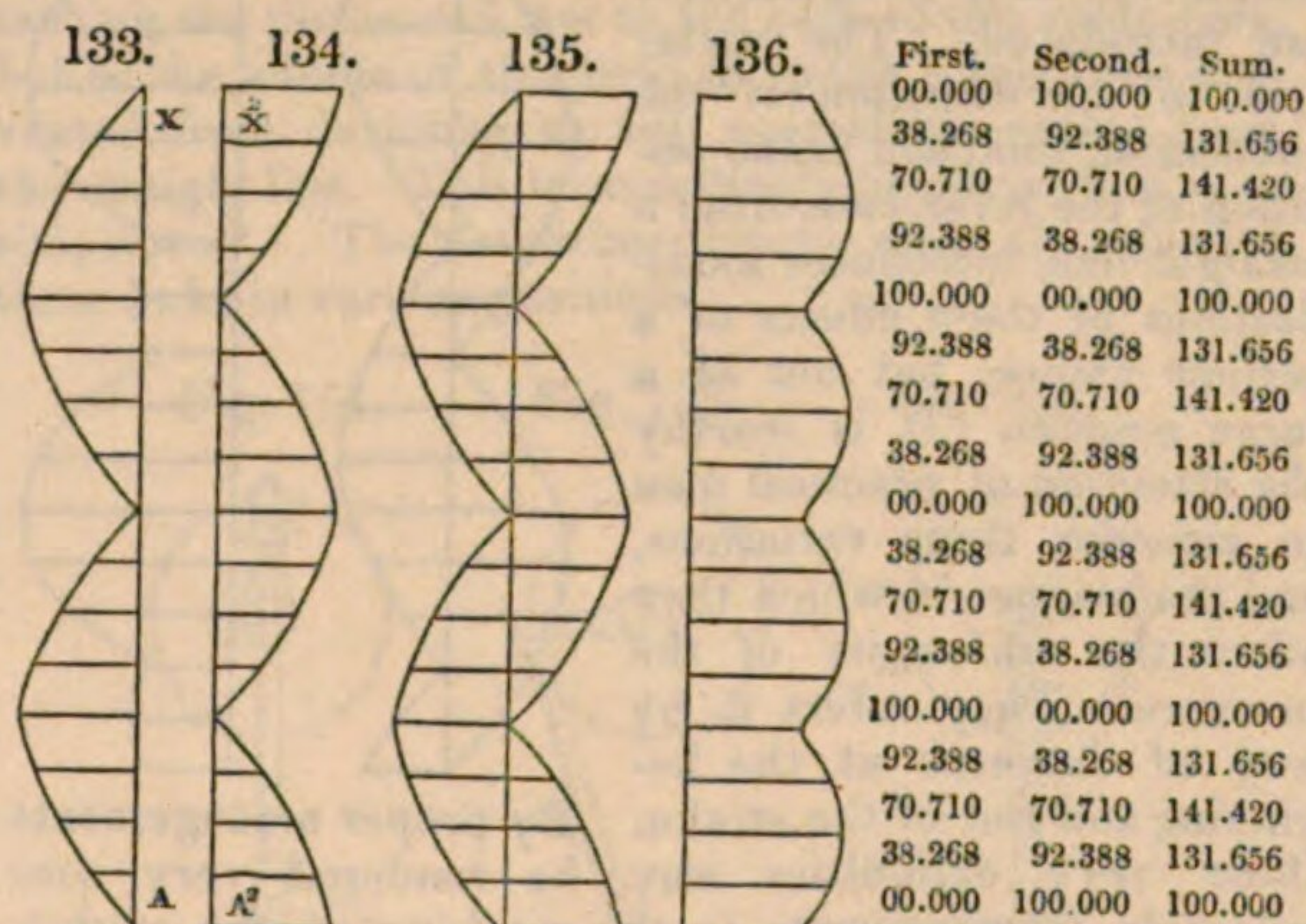
crank be represented by the straight line A X, fig. 128, and divided into any number of equal parts; let straight lines $y^1 y^2 y^3$ &c., be drawn to represent the amount of pressure converted into the direction of the motion of the crank, according to the line b in fig. 127, being the amounts represented in the line of figures, then the curved line A $y y y x$ passing through the summit of all these lines will represent the variation in the power of the crank at each instant of time, each ordinate $y^1 y^2 y^3$ being the pressure, and the area of the whole figure will represent the whole motive power, having a maximum of y^5 and y^{15} , and a point of change of direction from pressure one way to pressure the opposite way at y^{10} .

Now one method of equalizing the rotative pressure on the crank has been proposed, and is very generally adopted, viz. to make two steam-engines act on the same axis by means of two cranks at right angles to each other, so that when the one ceases to exert force, the other may be at its point of greatest force.



Thus in the figures 129 to 132 two cranks are represented as coming from two cylinders, and attached to the same axis, so that when the one of them is at 0, the other is at 5, when the first is at 5 the second is at 10, and so on; so that while either is on the line of cessation of force, the other is at the point of maximum.

The joint effect of two such cranks may be represented by curves in the following way:—



Let the circumference of each crank circle be represented by the lines A X and A² X² as formerly, each semi-circumference being divided into eight parts, and let the pressure be calculated from a table of sines, where each will be found as the sine of the arch of the circumference to which it corresponds; the numbers thus obtained being arranged on the right of the figures, so as to obtain by the two curves the representation of the varying quantity of force, but without regarding the reversion of direction. If now we place these curves together, as in fig. 135, their whole ordinates taken across from the one curve to the other, will truly represent the amount of the sum of the forces and its variation; and if we place all these ordinates from a fourth axis, we shall have truly represented, by the new curve fig. 136, the variations of the sum of the forces of the two cranks. The figures in the third column represent the sums of the ordinates, in which it is shown that the maximum is 41 per cent greater than the minimum pressure, even when two

Steam-Engine. cylinders are made to act on cranks at right angles to each other. The whole of this calculation is summed up in the following formula:

Analysis of the action of the Combined cranks.

Let r be the radius of each crank,
 x the effective leverage of one,
 $\therefore \sqrt{r^2 - x^2}$ is the effective leverage of the other,
 and $x + \sqrt{r^2 - x^2}$ the sum of the pressures,
 from which we obtain, by differentiating
 $x = \sqrt{r^2 - x^2}$ in the case of a maximum,
 and when $x = 0$, the sum $x + \sqrt{r^2 - x^2}$ becomes $= r$
 or when $\sqrt{r^2 - x^2} = 0$, $x + \sqrt{r^2 - x^2}$ becomes $= r$
 and when $x = \sqrt{r^2 - x^2}$, $x + \sqrt{r^2 - x^2}$ becomes $= 2r$
 $\sqrt{2} r$
 $= 1.411$.

Hence the point of greatest pressure is at 45° from the minimum, and the minimum sums at the termination of each quadrant, the maximum being to the minimum as the square root of 2 to unity.

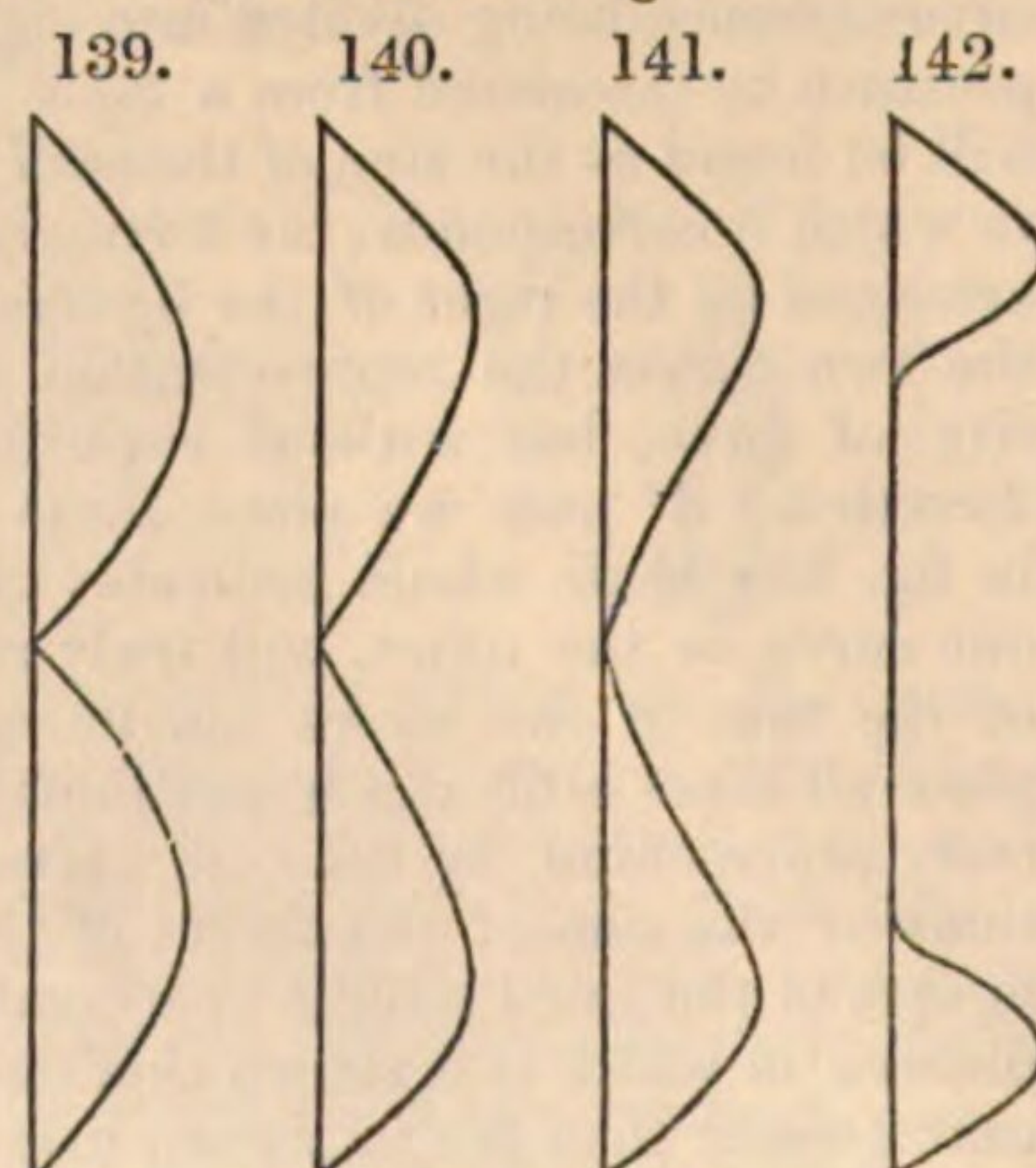
It is obvious then, in conclusion, that with two engines the variation above the mean, amounts to about 12.6—141=15 in 126, or about eleven per cent, and that the decrease below the mean amounts to twenty per cent.

It is a matter of some difficulty to decide at what angle the cranks should be placed in a double engine, so as to give the best effect. If we place them at a greater angle than 90° apart, the minima become small, and the maxima, however, are by no means sudden. If we place them at a less angle, the maxima become excessive; and although the minima be larger, the maxima are also larger. The following diagrams, 137, 138, show the effect of these two methods.

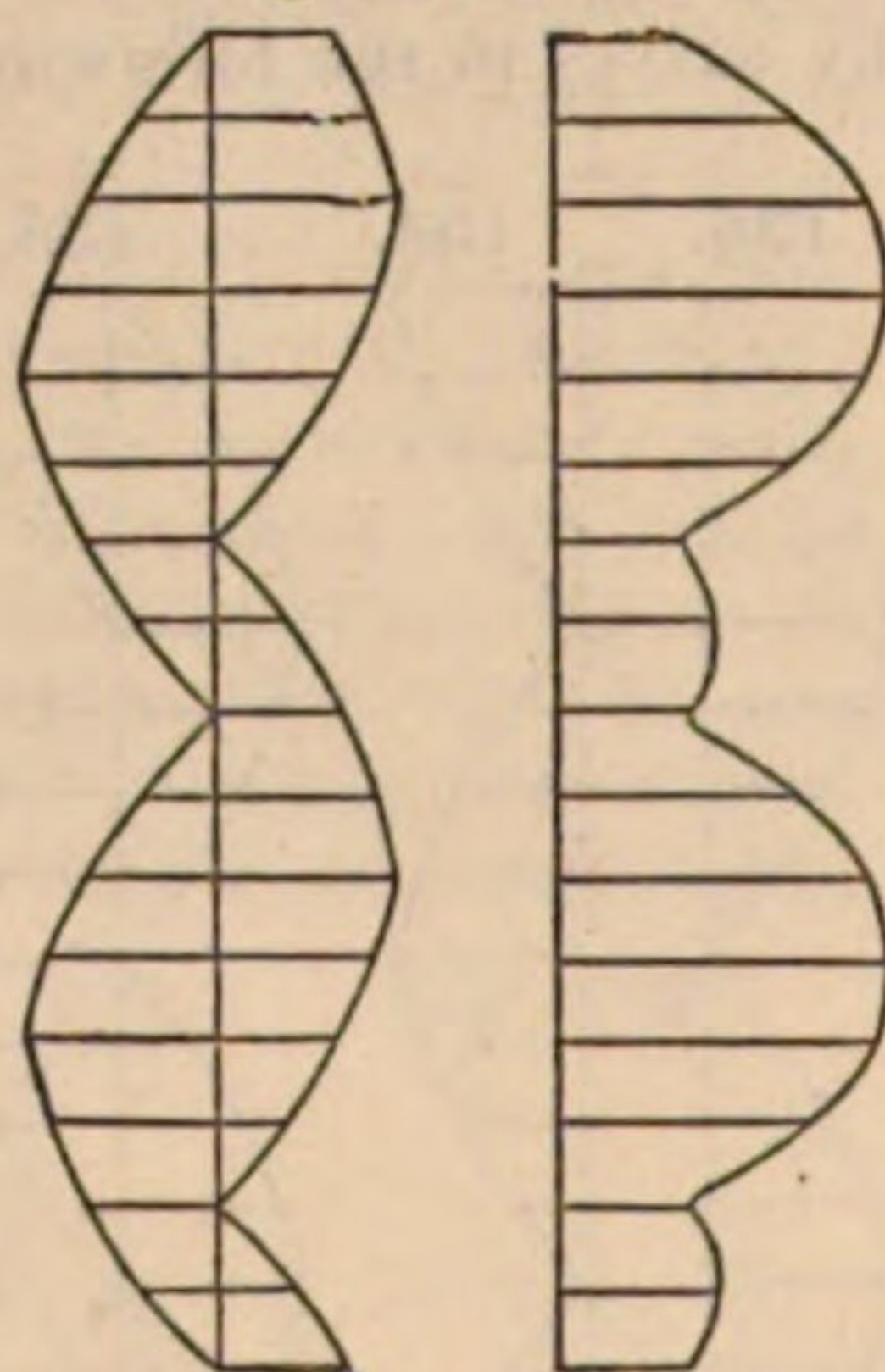
Effect of the crank-rod on the Crank's action.

When a lever intervenes between the crank-rod and the piston-rod, new irregularities are introduced. The variation in the direction of the connecting link, and in the position of the lever-ends from a straight line, introduces modifications of these effects of a serious nature, but not of a large amount. It is worthy the attention of practical men to consider these variations, and the manner in which they affect the uniformity of the pressure. They affect it by way of increase at the beginning and end of the stroke. By proper arrangements these very obliquities may be rendered very considerable improvements in the working of the engine. It should also be observed that the stroke of the piston and crank will not remain of the same length.

The agency of the crank in transmitting a force parallel to the piston-rod has been represented by the curve of sines, as in fig. 139. But if we represent, in a similar way, the pressures produced by the obliquity of the crank-rod, we shall find the form become that given in the following figures.



Figs. 137, 138.



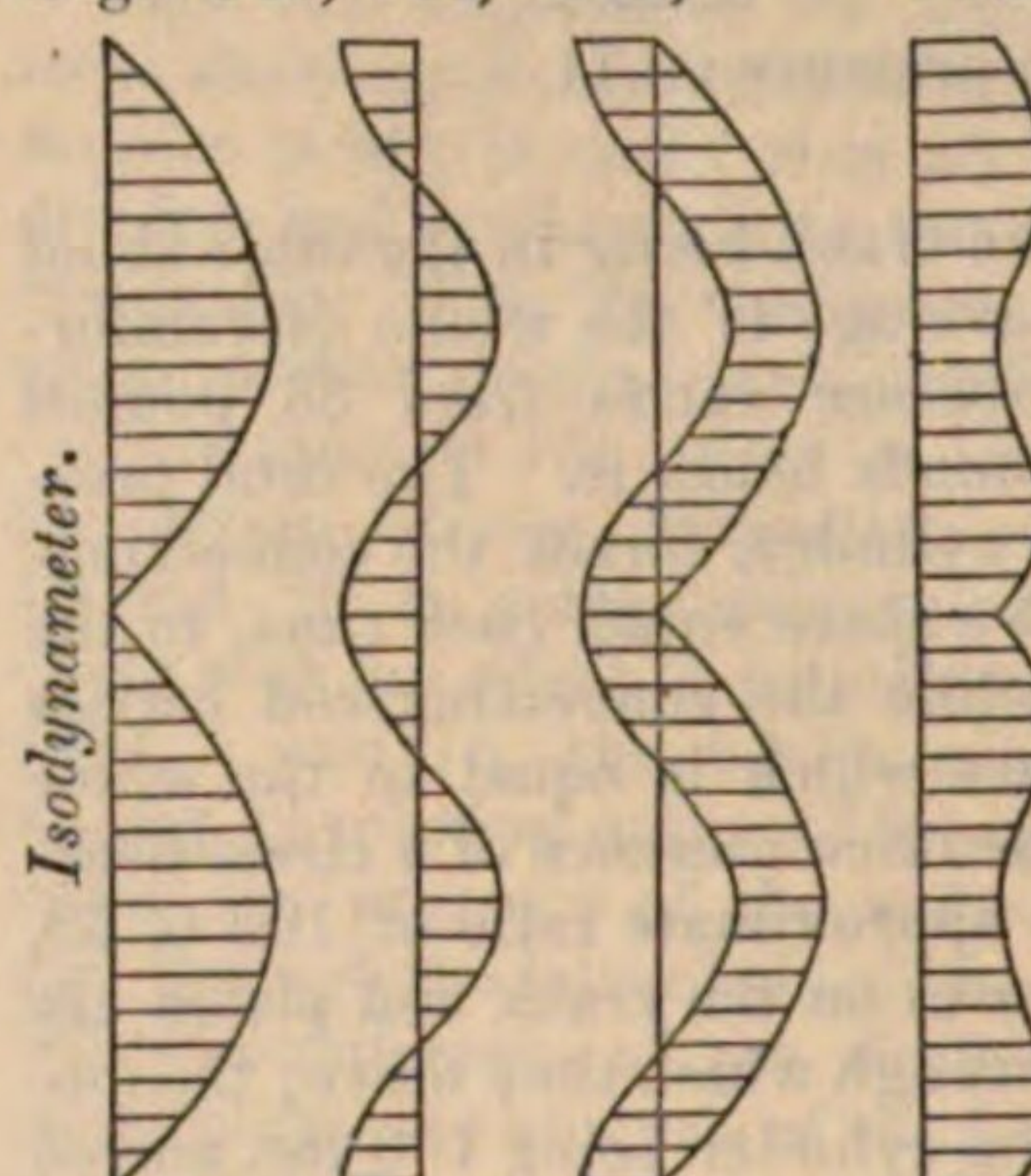
By proper arrangements these very obliquities may be rendered very considerable improvements in the working of the engine. It should also be observed that the stroke of the piston and crank will not remain of the same length.

Fig. 140 represents the variation of pressure with a crank-rod of four times the length of the crank, fig. 141 with a crank-rod of double the length of the crank, and fig. 142 with a crank-rod equal to the length of the crank.

It is obvious, that with the shortening of the crank-rod, the irregularity of the motion becomes very great. Two maxima rapidly succeed each other, and these are wide apart from the next pair. Thus two violent pressures succeed at a short interval, and a long pause intervenes, when the force is very small.

By the same system of curves we may proceed to examine the pneumatic equalizer of Mr Buckle. Let the rotative pressure of the crank be again represented, as formerly, by the curve in fig. 143. And let the rotative

Figs. 143, 144, 145, 146.

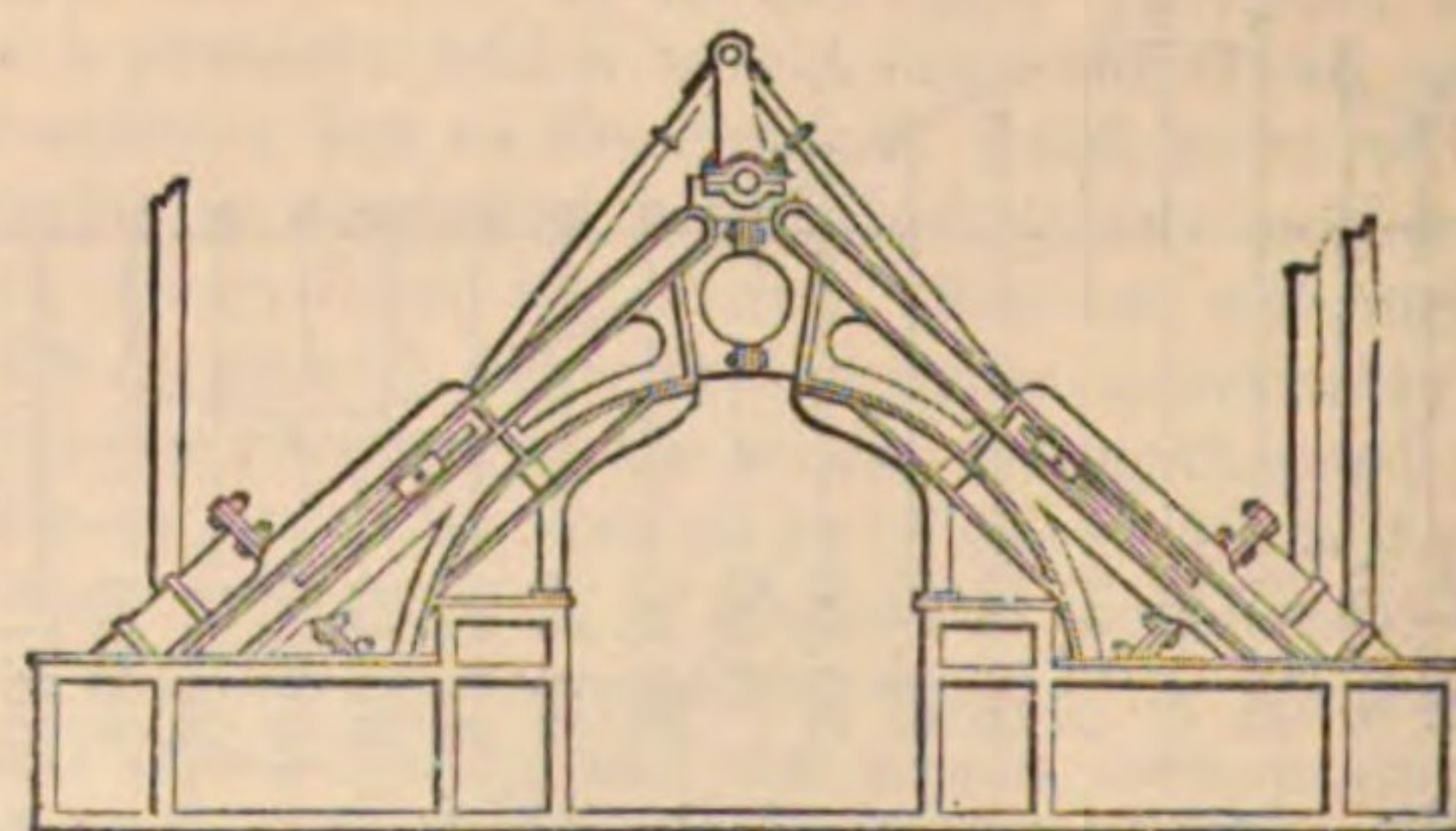


0.000	50.000	50.000
19.509	46.194	55.703
38.268	35.345	73.623
55.555	19.134	74.686
70.710	00.000	70.710
83.147	19.134	64.013
92.388	35.355	57.033
98.078	46.194	51.864
100.000	50.000	50.000

pressure of the pneumatic crank of the equalizer be represented by the curve in fig. 144, lying on alternate sides of the axis, so as to show the alternate coincidence with, or opposition to, the action of the steam-crank. Then if we place the two axes as in fig. 145, the lines between the two curves will represent the sums of the pressures; and if we set off these intercepted parts in a third curve, we shall get the line representing the variation of the resulting force, corresponding to the sums and differences of the former ordinates. The values of these are given in columns of figures on the right through one quadrant. The mean value 63 is in this case exceeded by 19 per cent, and is receded from below by nearly 20 per cent. The deviation from the mean pressure is not, therefore, greater than 20 per cent, and the equalization produced by Mr Buckle's pneumatic equalizer is as sufficient as a pair of engines, and much less complicated and expensive.

Still, however, it is to be noticed, that as there is a variation of force amounting to about 20 per cent above or below the mean, with a pair of engines as well as with the pneumatic reservoir of power, it is obvious that the combination of a fly-wheel with either of these systems of arrangement, would be required to obtain the nearest possible approximation to uniformity in cases of delicacy.

Fig. 147.



Steam-Engine.

Effect of the Crank-rod.

Instead of using two cranks for the purpose of applying the force of two steam-engines to the same axis of revolution, two engines have been used with their cylinders laid at right angles to each other, and having their connecting-rods applied to the same crank. For an engine of this kind, fig. 147, Mr. Brunel obtained a patent; and we have seen his machine working in a satisfactory manner. An arrangement of a similar description has also been introduced in steam-boats by M. Cave of Paris.

Of the Connecting-rod and Parallel Motion.—In considering the agency of the crank in modifying the force and velocity of steam, so as to connect its direction and distribute its force in the manner required to produce a rotative motion in the machinery, from the original reciprocating motion of the piston in the cylinder, we have hitherto avoided the introduction of another important element, by which a further variation of force and of motion is produced. The connecting-rod is a rigid bar of metal which conveys the motion of the piston from the piston-rod to the crank either immediately or through the interposition of the lever or beam; and as the connecting-rod, in doing so, takes various directions different from those either of the piston-rod or of the crank, there is an obliquity of pressure produced at both extremities of the connecting-rod, which gives rise to a variation of force and of direction, which must be practically provided for, and carefully appreciated in quantity, in so far as it may affect the ultimate operation of the machine.

There are two ways in which the motion of the piston-rod is most commonly transferred to the crank; either immediately through the connecting-rod, as in fig. 148, or through the medium of the great lever, as in

Fig. 148.

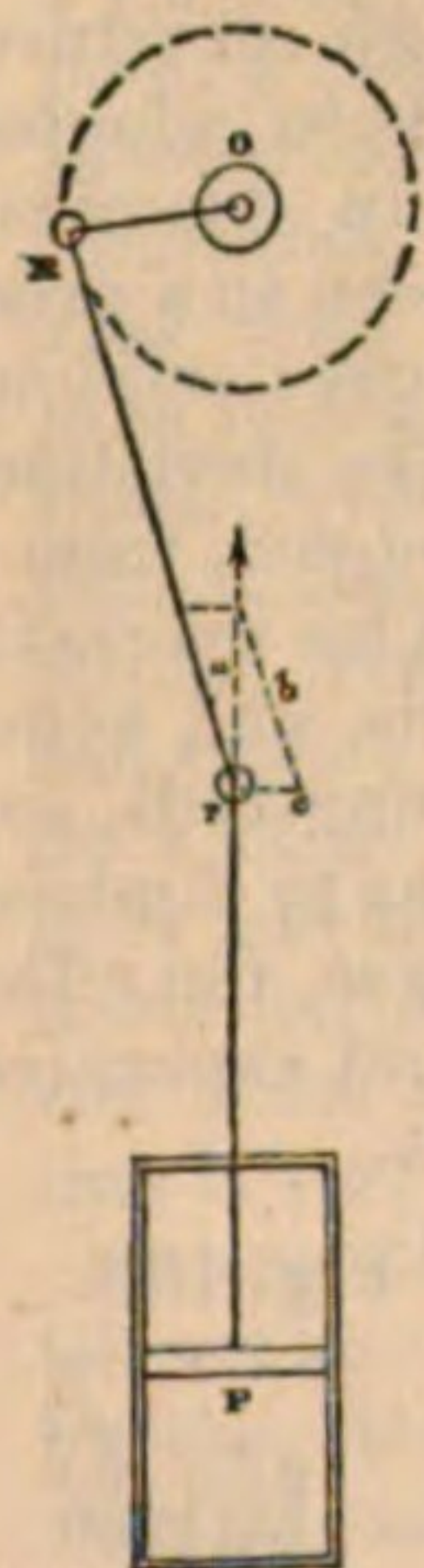


Fig. 149.

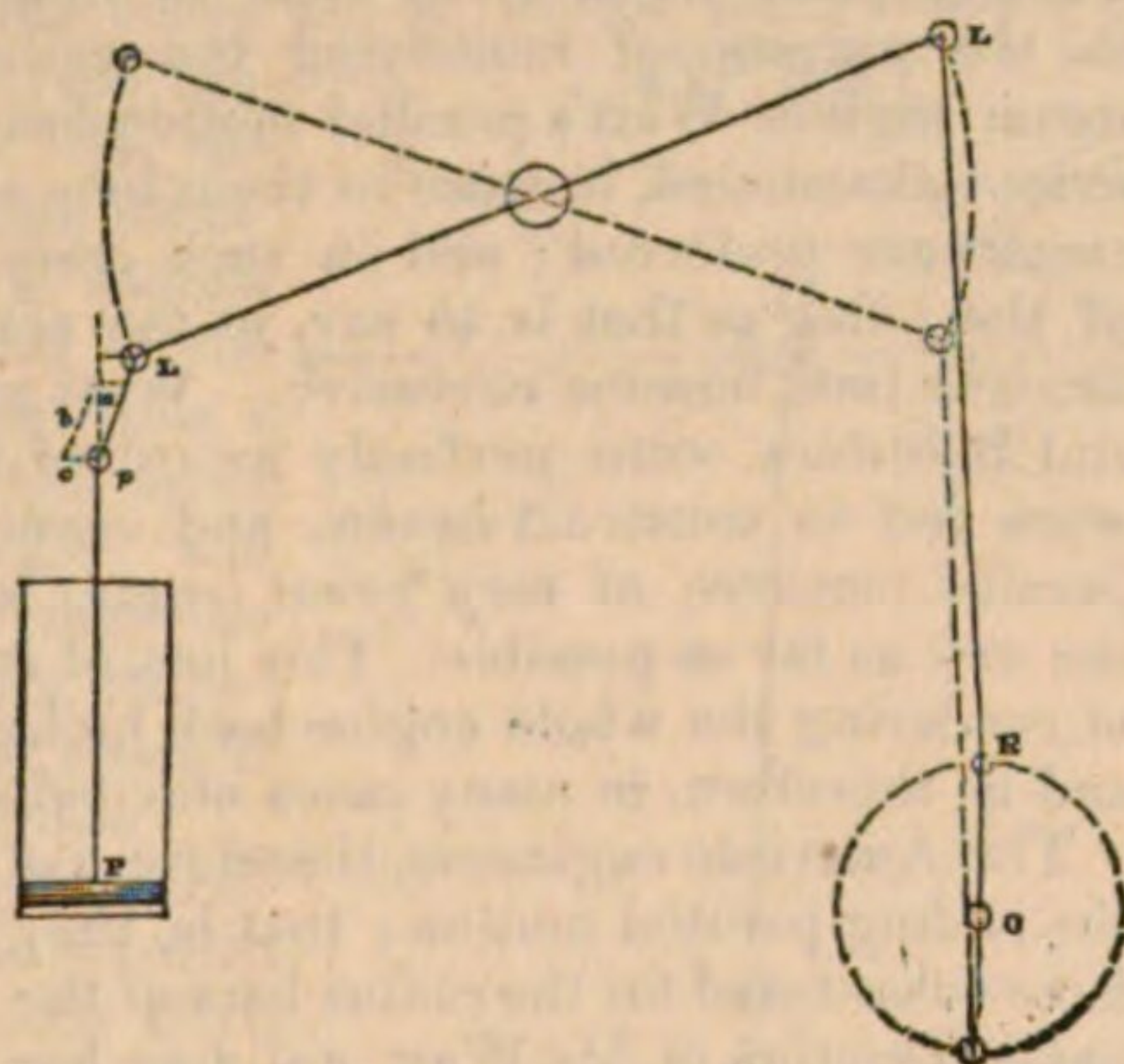


fig. 149; both ends of the great lever describing circles around its middle fulcrum as a centre, and the head of the piston-rod being connected with the one end of the lever by means of an iron strap or connecting link. From inspection of the figure, it becomes plain that the connecting rod or link, is never, except at two points, in the same straight line with the piston-rod, so as to propagate its unmodified force to the crank, but that in these oblique positions it would produce a lateral motion in the end of the piston-rod which would not only be a waste of power in producing motion in a place where it is useless, but would have the effect of continually bending the piston-rod in opposite sides so as either to break it, or materially to impair its working. In the first of these figures, Pp being the direction of the piston-rod, pR that of the crank, the force in the piston-rod in the direction pa becomes resolved into two parts pR and pc ,

VOL. XX.

pR being effective in the direction of the crank-rod, and pc tending only to give lateral motion to the piston-rod, or else to bend it, or else break it across. And so also in the second figure there is a similar separation of pressure.

To prevent these lateral pressures from wasting the power of the steam, by producing lateral, useless, or injurious motions, is the object of a series of contrivances called parallel motions, or parallel guides. The most notable of these we owe to Mr Watt.

Let it be supposed that we desire to prevent the top of the piston-rod p , fig. 150, from being moved by the obliquity of the connecting-rod pR , either towards the right or the left, then it is accomplished in the following way. A fixed support, s , is found on one side of the piston-rod, and another on the other s' at equal distances from it, and two parallel bars gs and $g's'$ are placed between the piston-rod and these points, so that it may be steadied between them. These parallel bars are made so as to revolve freely round the points s s' as centres, each of the ends g g' describing the circles g g^2 g^1 g^3 , from which it is evident that if these rods were directly attached to the piston-rod at g and g' , they should have the effect of keeping the point p in the straight line og $g'p$. As these bars sg and $s'g'$ must describe circles round s and s' , they would, in the positions sg^2 $s'g^3$, deviate altogether from the straight line of the piston-rod; but as the one will act nearly as much in the one direction as the other in the opposite, it occurred to Mr Watt that, by connecting their extremities with a link, gg' , and attaching the piston-rod, not to the ends of the guide-bars, but to the middle of this link, the point p might be prevented from deviating to any appreciable extent from the straight line. This is accordingly produced in a very simple way. The following figures show the effect of these links in various positions.

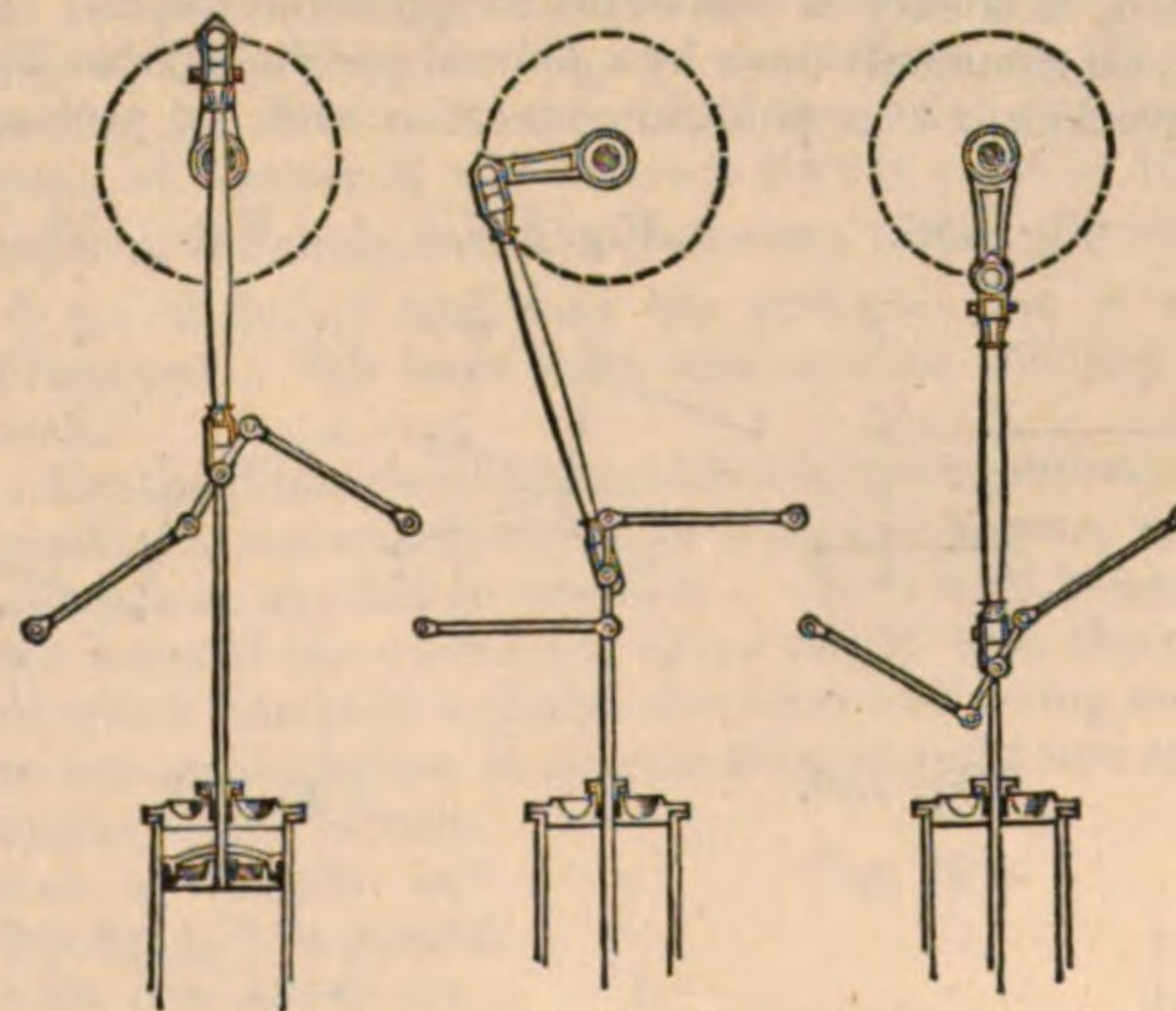
Fig. 150.



Fig. 151.

Fig. 152.

Fig. 153.



This elegant and simple contrivance is not, however, Watt's absolutely perfect; and, in accurate workmanship, and on parallel a larger scale, great allowance requires to be made for its errors, or it will produce very many serious derangements of the machinery to which it is applied. By this arrangement the point p is not kept perfectly in a straight line, but is, on the contrary, compelled to deviate from it

Steam-Engine.

Parallel motion of Watt.

Steam-Engine.
Watt's Parallel Motion.

so as to describe a looped curve. The nature of this deviation will become very evident if we suppose the parallel motion to be altogether detached from the piston-rod, and the motion of the parallel bar and link carried to its extreme, as in the following figures, 154, 155. A pencil being used to trace the motion of the middle point, p will describe, not a straight line, but the curve $p x y$. When we carry the rods up to the position represented in the first of the following figures, where the bar $g s$ comes into the straight line with the link $g g$, the point p deviates from the straight line by a quantity equal to p' , and this is reversed in the opposite extreme. In the next figure the deviation is much greater when the link $g g$ comes into the same line with the other bar $g s$, and is also reversed in the position at the bottom of the figure. By the time the links have been returned to their primitive position, they have described the curve $x p y$.

Fig. 154.

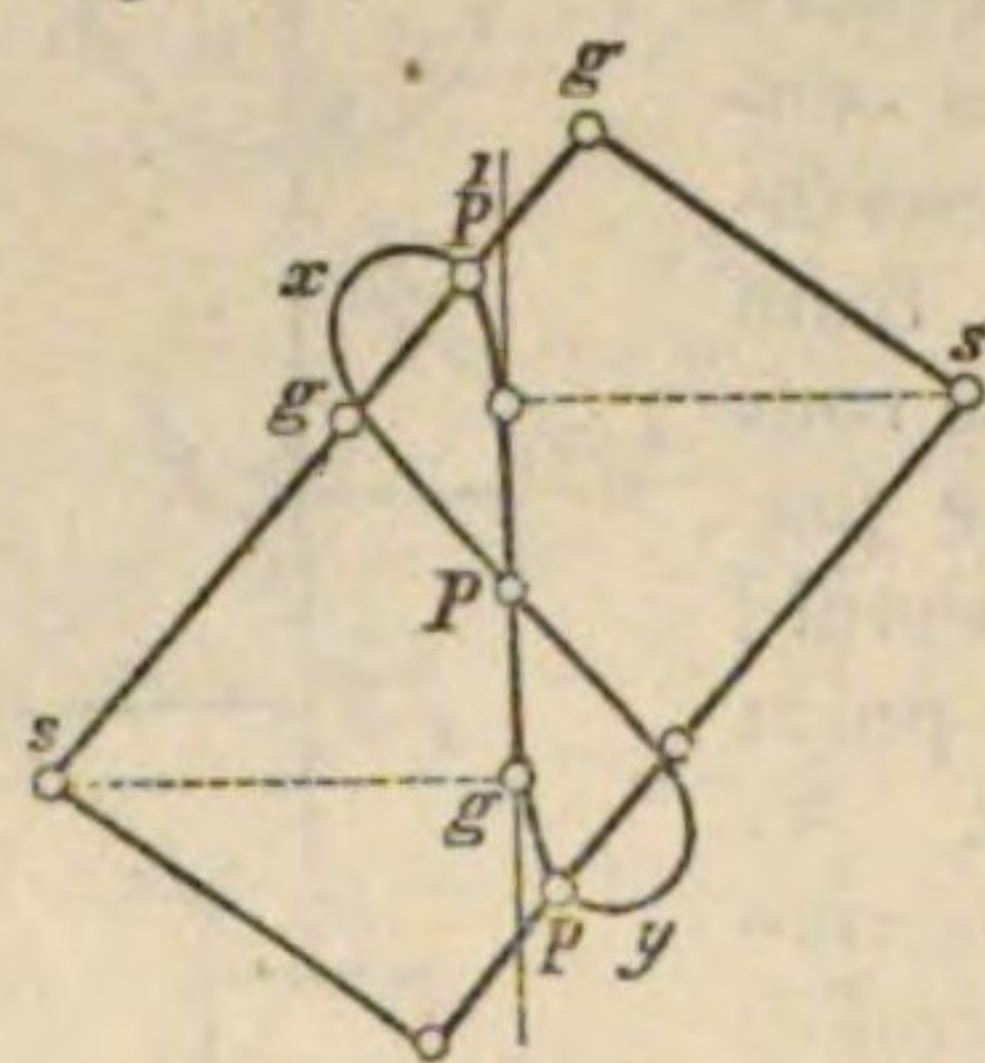
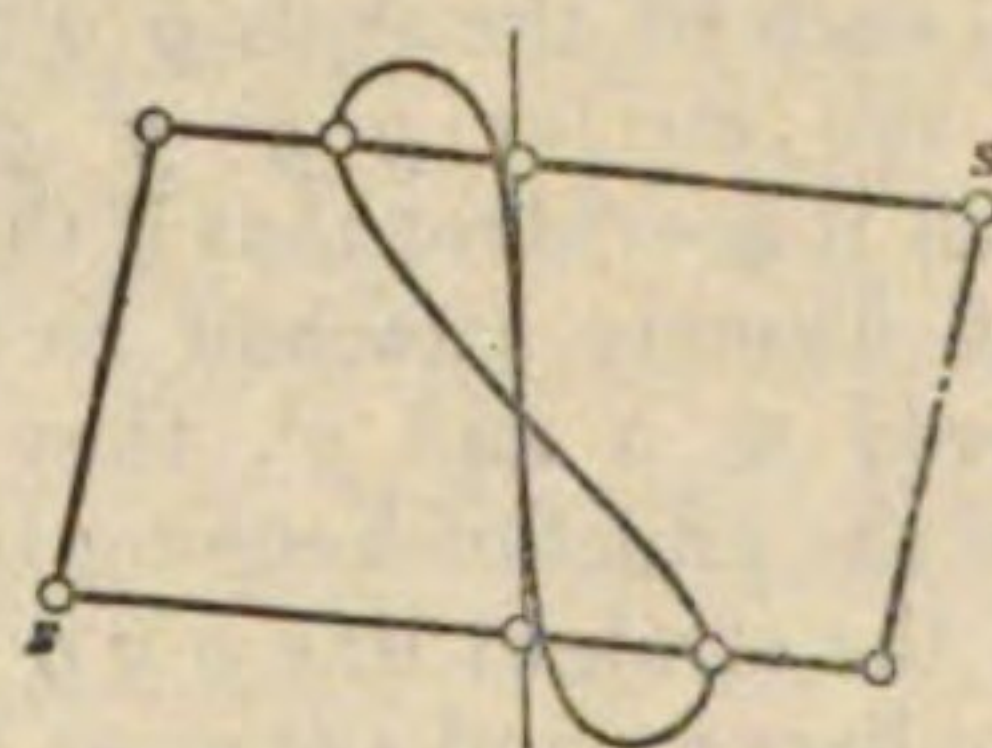


Fig. 155.



It is important to diminish the amount of this deviation, which increases more rapidly than the square of the length of the stroke. Having ascertained the amount of greatest deviation at the end of the stroke, and also the amount at $\frac{1}{8}$ th part of the stroke from the middle, bring the centres s and s' each nearer to the other by a quantity equal to the deviation at the said $\frac{1}{8}$ th part, and the amount of the greatest deviation will now be reduced to less than one quarter of its former amount: the curve will now become a line of the sixth (eighth?) order.

The parallel motion of one point having thus been secured, it is easy to transfer it to any other point. This is most commonly done by a jointed parallelogram. Thus, to transfer it to a point in connexion with $s g$ prolonged

Fig. 156.

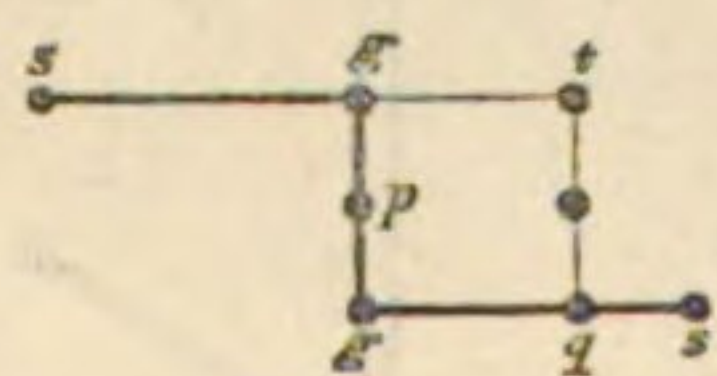


Fig. 157.

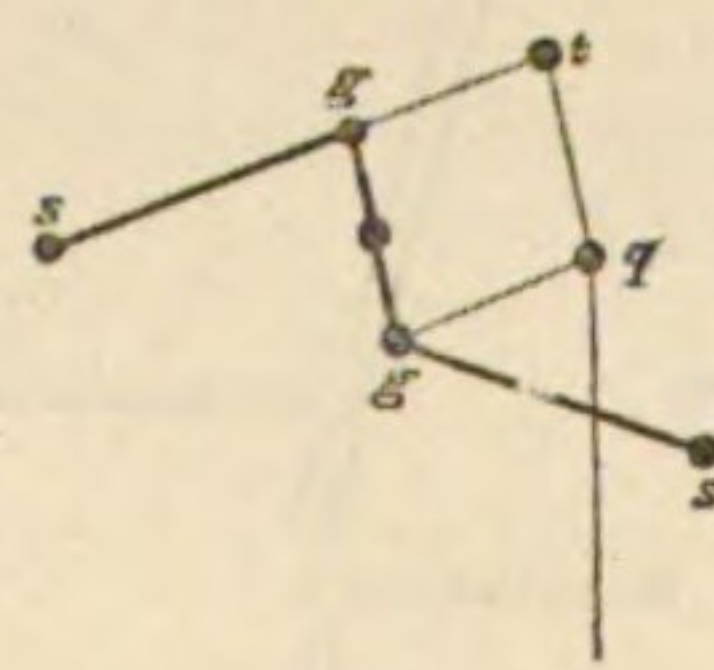


Fig. 158.



Fig. 159.

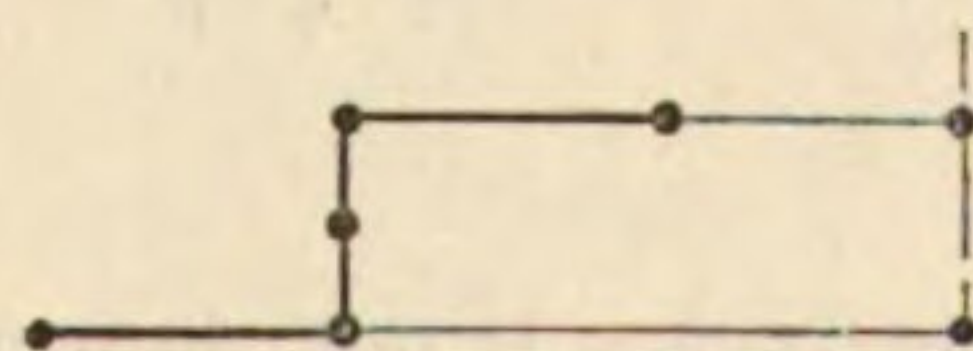
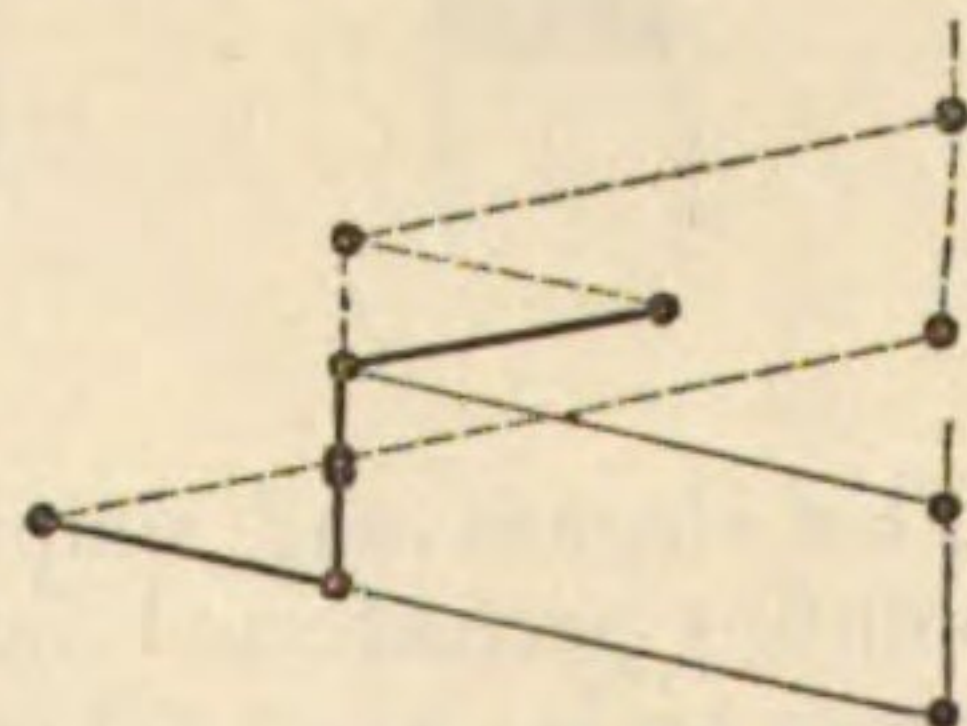


Fig. 160.



to t , (figs. 156 to 158) take a second link $t q$, equal to $g g$, and a second bar, called the parallel bar $g q$, equal to $g t$, the corner q of the parallelogram will give a motion $t q$

similar to p . Figs. 159, 160, show the parallel motion transferred to a point still farther from the original point.

Another form of Mr Watt's invention consists in placing two bars in the same direction, with such a difference in their length, that the excess of the continuance of the one above the other may afford the means of compensation. Suppose that the point p , fig. 161, is to be guided to move in the straight line $p g g'$; $s s'$ are points on the same side of the required direction of motion, and $s g s' g'$ are the differential bars connected by a link $g' g$,

Fig. 161.

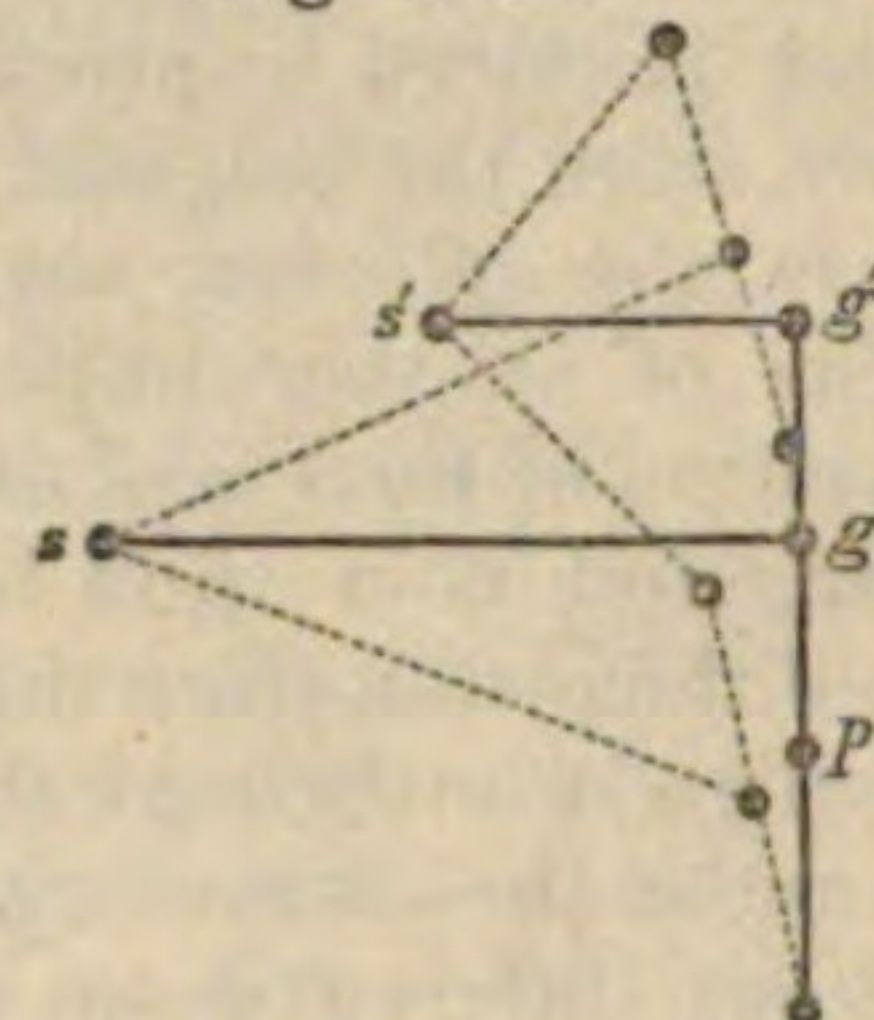
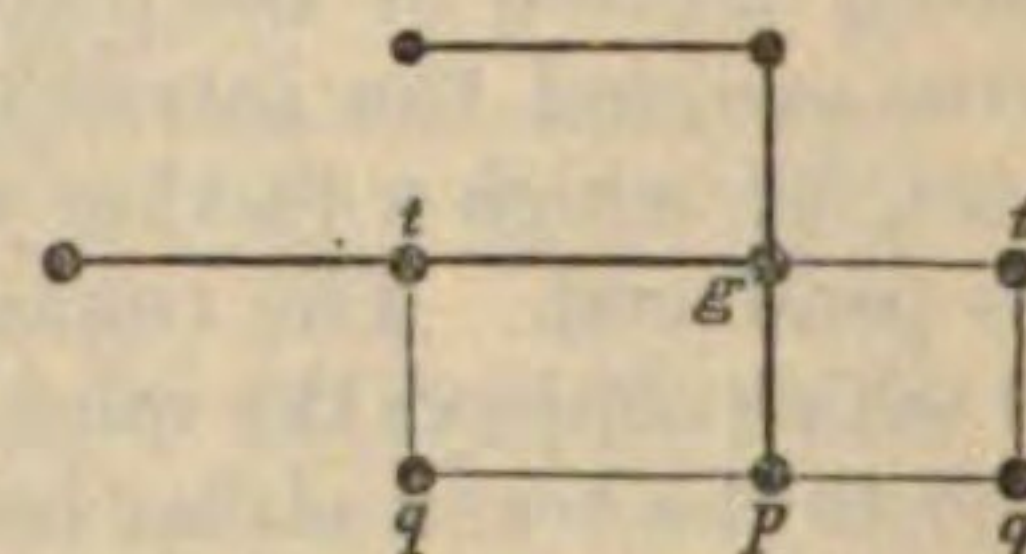


Fig. 162.



which is prolonged to p . The dotted lines of the figure show the bars in different positions. The line described by the point p is not a straight line, but a curve, like figs. 154, 155. The motion of the point p may be transferred to a distance, as in the former instance, by a jointed parallelogram $g p t q$, fig. 162. All these parallel motions may be inverted, and, indeed, generally are inverted in steam-boat engines. For practical examples of them, the reader may consult the plates.

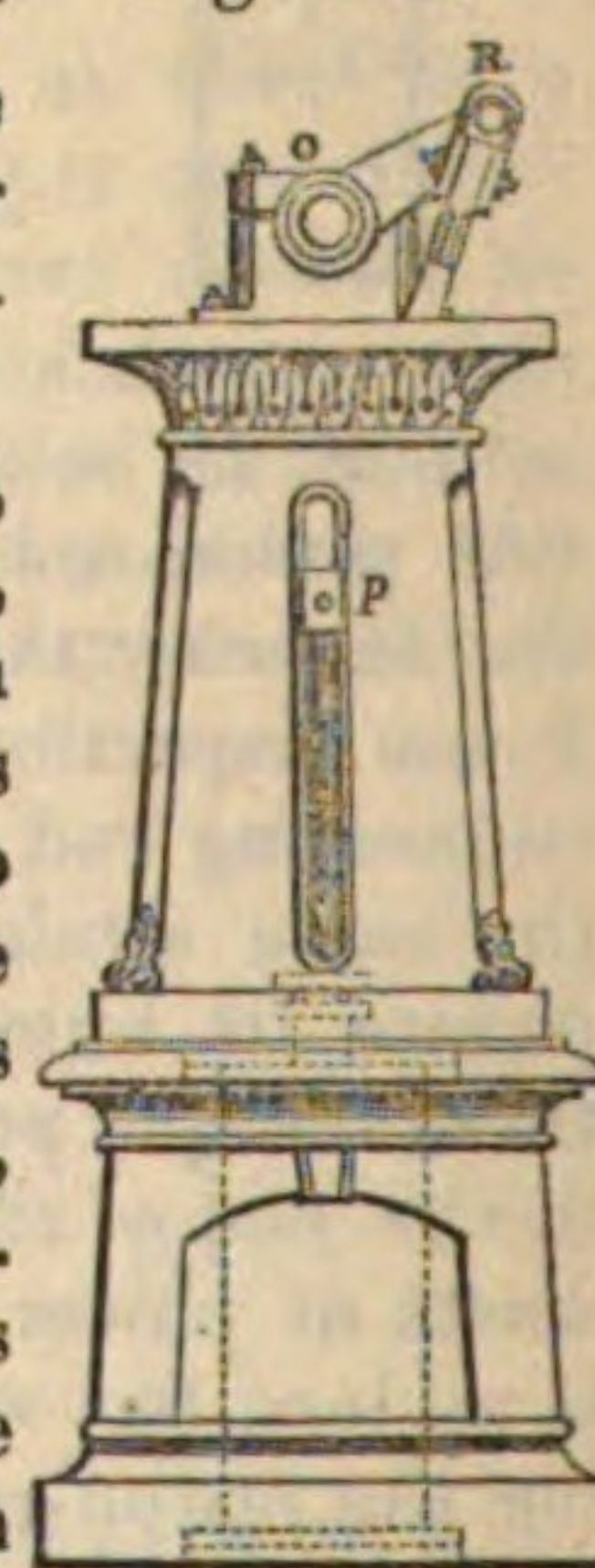
All these motions are imperfect; that is to say, the motion of the end of the piston-rod does not take place in a perfectly straight line, but possesses high curvature. Various plans have, from time to time, been adopted for the purpose of remedying the evil. In American steam-engines Watt's parallel motion has been to a great extent abandoned, because in them long strokes and long cranks are preferred; and in such cases the deviations of the point p , that is to say, of the piston-rod, from a straight line, become excessive. Watt and his assistants and followers were perfectly aware of this, and hence were led to construct beams, and connecting-rods, and parallel motions, of *very great length*, so as to diminish the evil as far as possible. This has, of course, the effect of rendering the whole engine both bulky and expensive, and is, therefore, in many cases inexpedient.

The American engineers, therefore, use the sliding parallel motion; that is, they have substituted for the radius bars of the parallel motion of Mr Watt, a sliding bar or groove in which the top of the piston-rod is guided.

The head of the piston-rod p , figs. 163, 164, is enclosed between two flat surfaces, or between two parallel iron bars, which are kept in the vertical position by means of stiff-framing: on these it slides, or to diminish the friction a wheel may be added; but there are reasons why this wheel does not in practice work very well, and the plain slide is therefore preferred. In fig. 163 we have represented this motion as applied to an engine of the simplest form, and in fig. 164 to a beam engine.

Another species of parallel motion was, we think, first adopted in America, but it has also been used in this country. It is the engine with vibrating pillar.

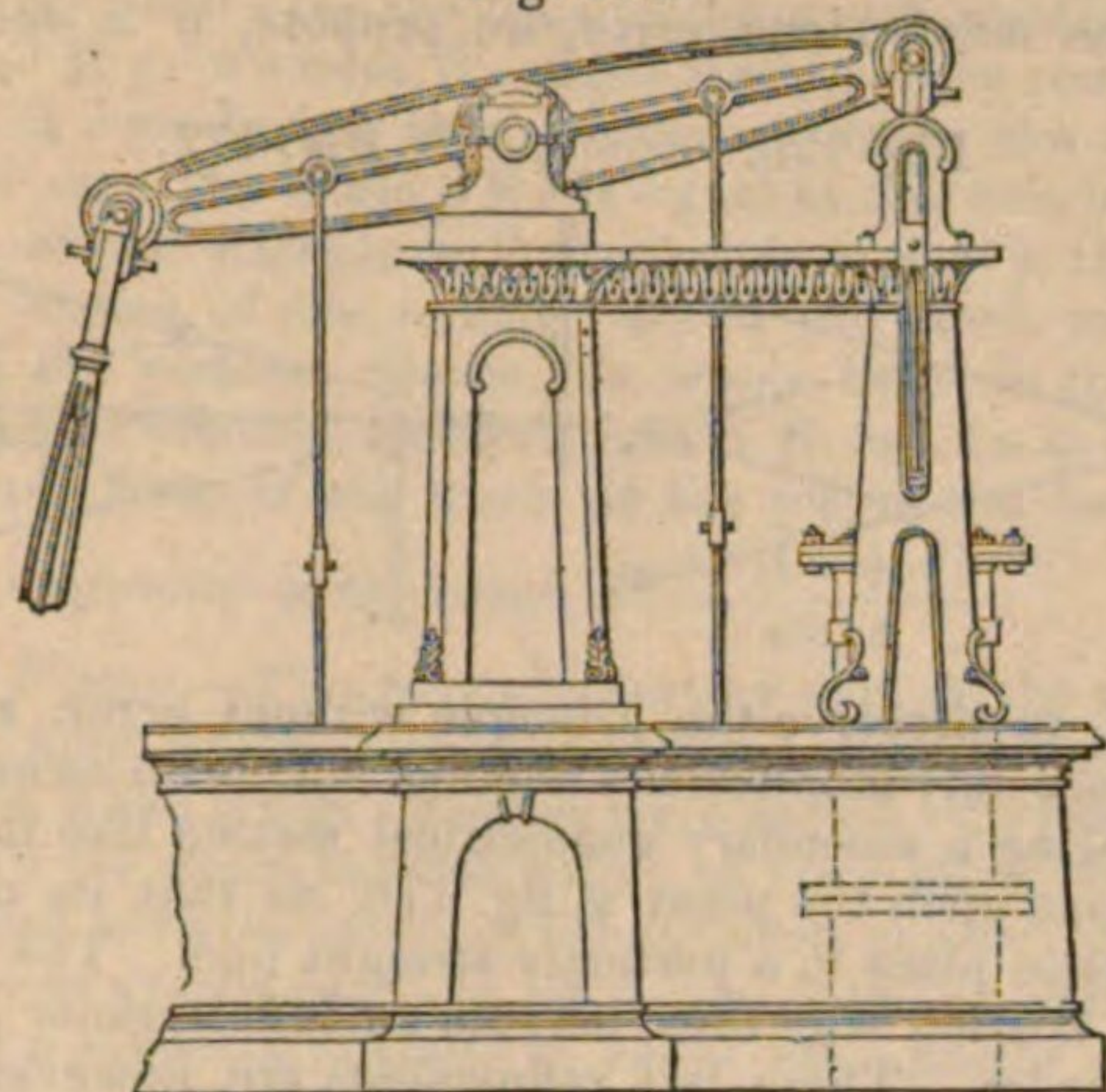
Fig. 163.



Sliding Parallel Motion.

Steam-Engine.
Parallel Motions.

Fig. 164.

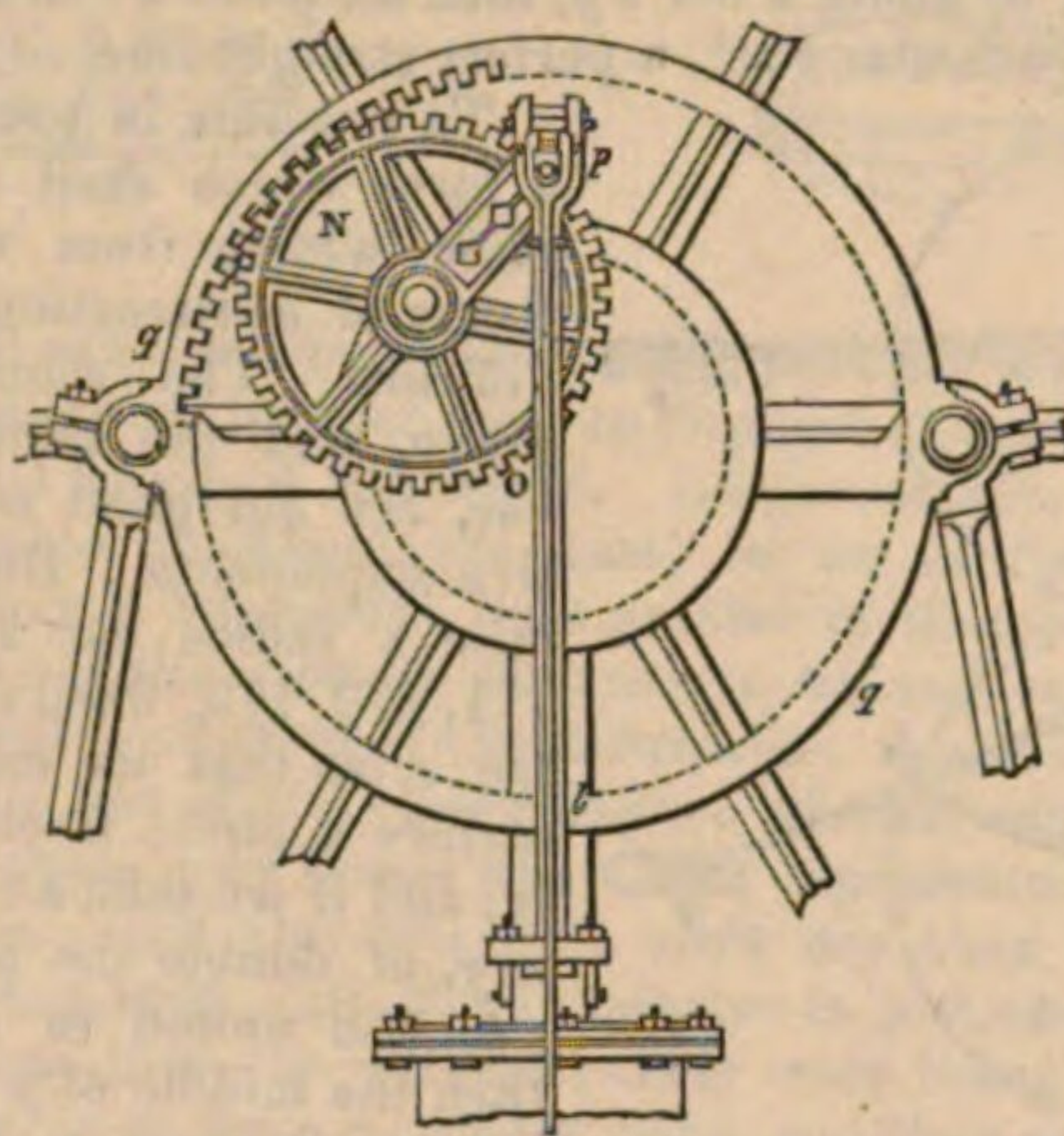


as 1797. Two equal toothed wheels *NN*, fig. 167, work into each other, and from corresponding points of their circumference two connecting links unite at the extremity of a cross bar, to the middle of which the piston-rod is joined. These wheels and connecting-rods being always in similar positions on opposite sides of the piston-rod, the obliquity of their actions balances each other, and the rod describes a straight line. But it is difficult to make and to maintain the wheels of this machine in the state of accuracy and perfection necessary to its working well.

Steam-Engine.
Parallel Motions.

The cycloidal parallel motion is one of high geometrical beauty. It was invented by Messrs Fenton, Murray, and Wood, and applied to the steam-engine in practice in 1802. It depends on this principle that an encycloidal curve, described by one circle rolling within another,

Fig. 168.



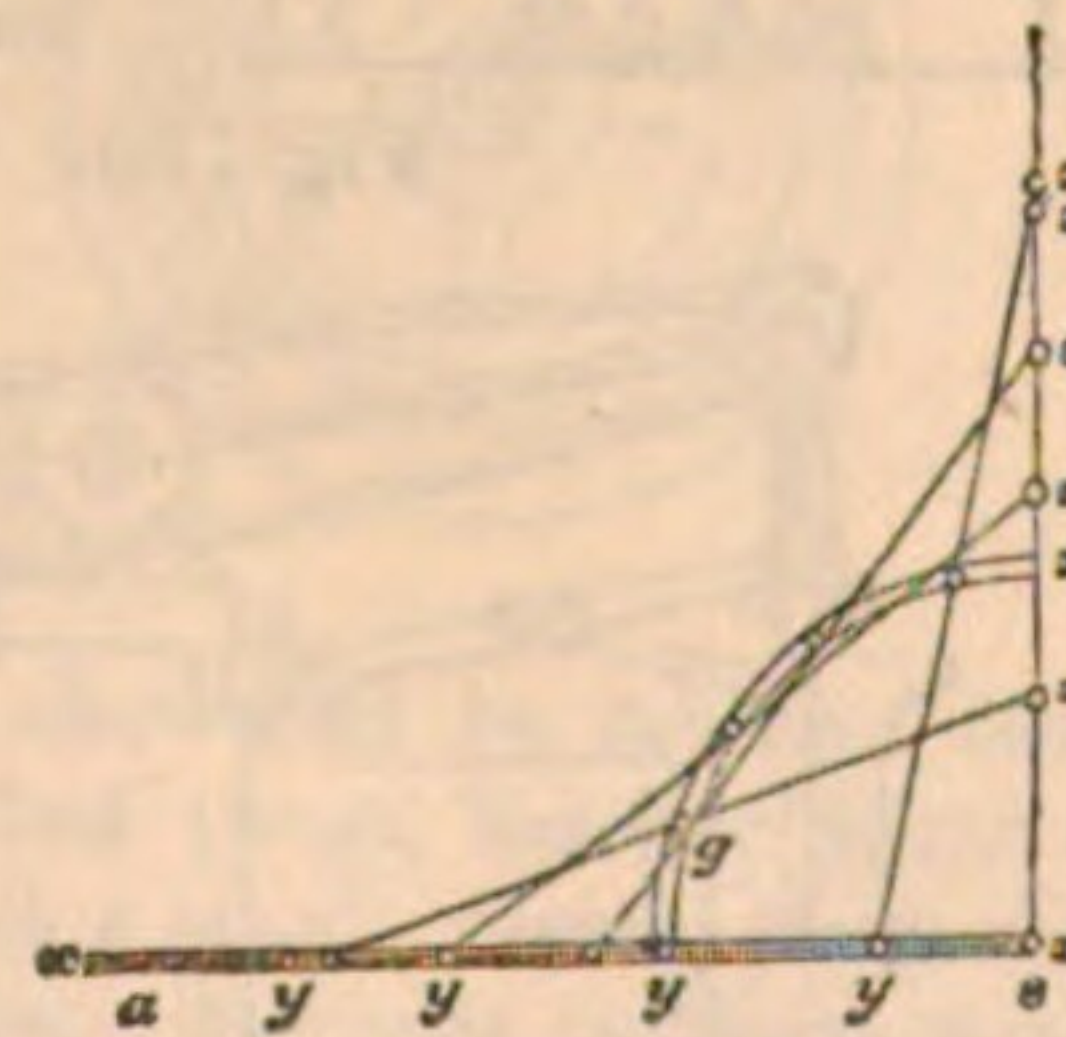
approaches a straight line as the inner circle becomes more nearly equal in diameter to the radius of the outer one. For the purpose of applying this principle, a large wheel *qq*, fig. 168, with teeth on its inner circumference, is fixed on a frame concentric with the axis and circle of the crank *OO*. *NO* is a wheel with external teeth, which is fixed freely on the crank-pin, and *p* is the point of attachment of the piston-rod *pl*. By this arrangement the small wheel *NO* is compelled, by the pressure of the piston-rod upwards, to roll round the great circle, ascending on the one side, and descending on the other, so that the distance of the end of the piston-rod from the point of contact of the circles is always equal to the distance of the circle from the diameter; (or, $n + r \sin e = \pm \frac{1}{2} r \cdot 2 \sin e$.) and thus the straight line is always preserved. We have seen this motion working very well.

But the principle which furnishes the most perfect parallel motion, is one which, although it be well known, we have never seen applied to practice. It is well known that the locus of the extremity of a straight line, the middle of which moves in a circle, the other end being confined to one straight line, is also another straight line at right angles to the former.

Perfect Parallel Motion.

Let a straight bar *xy*, fig. 169, be placed with one end *y* confined in an horizontal groove *as*, and let a pin in the middle *g* be allowed to slide in a circular groove *ygx*, then the end *x* will always describe a straight line *sx* perpendicular to the first.

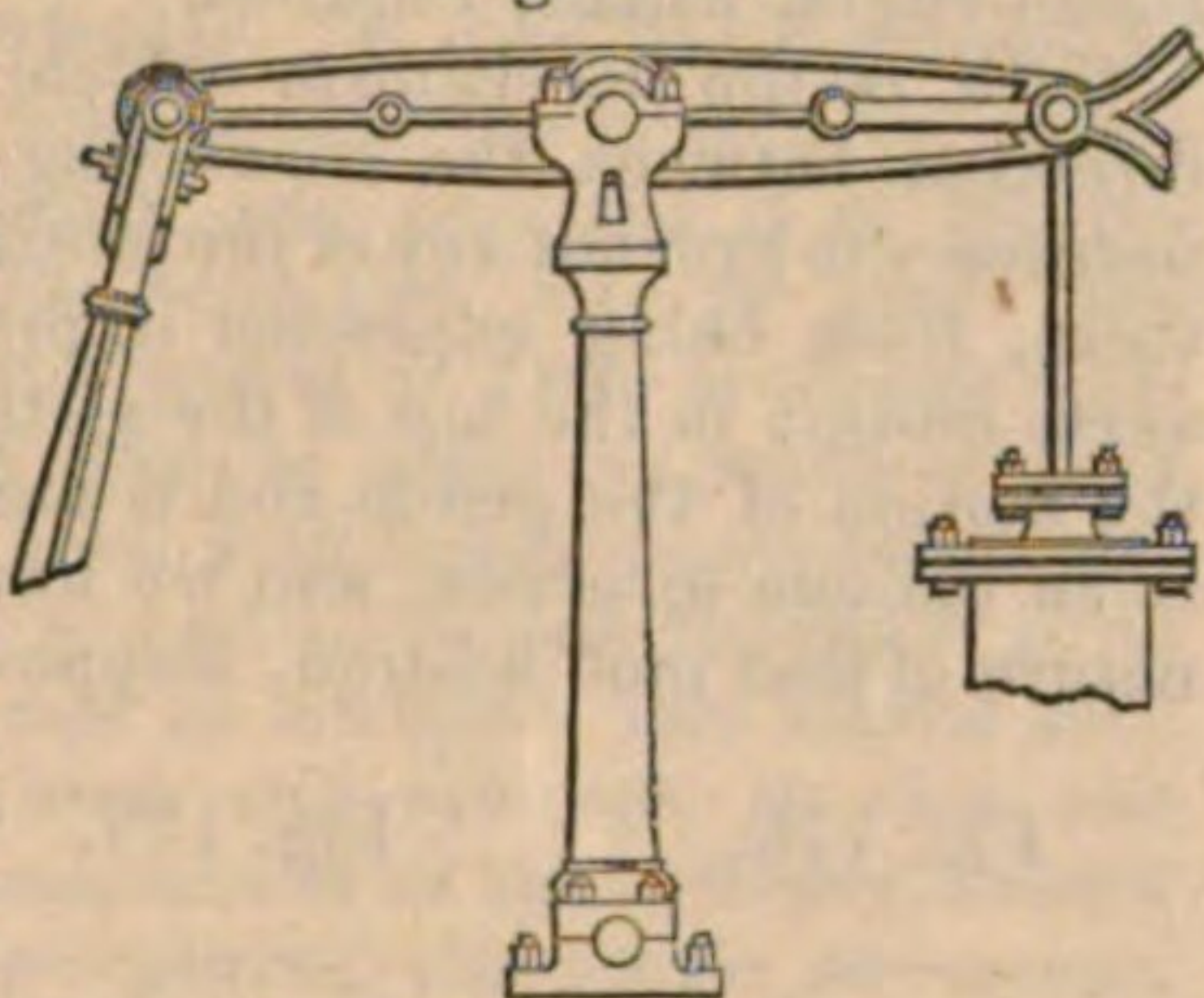
Fig. 169.



Vibrating Pillar Engine.

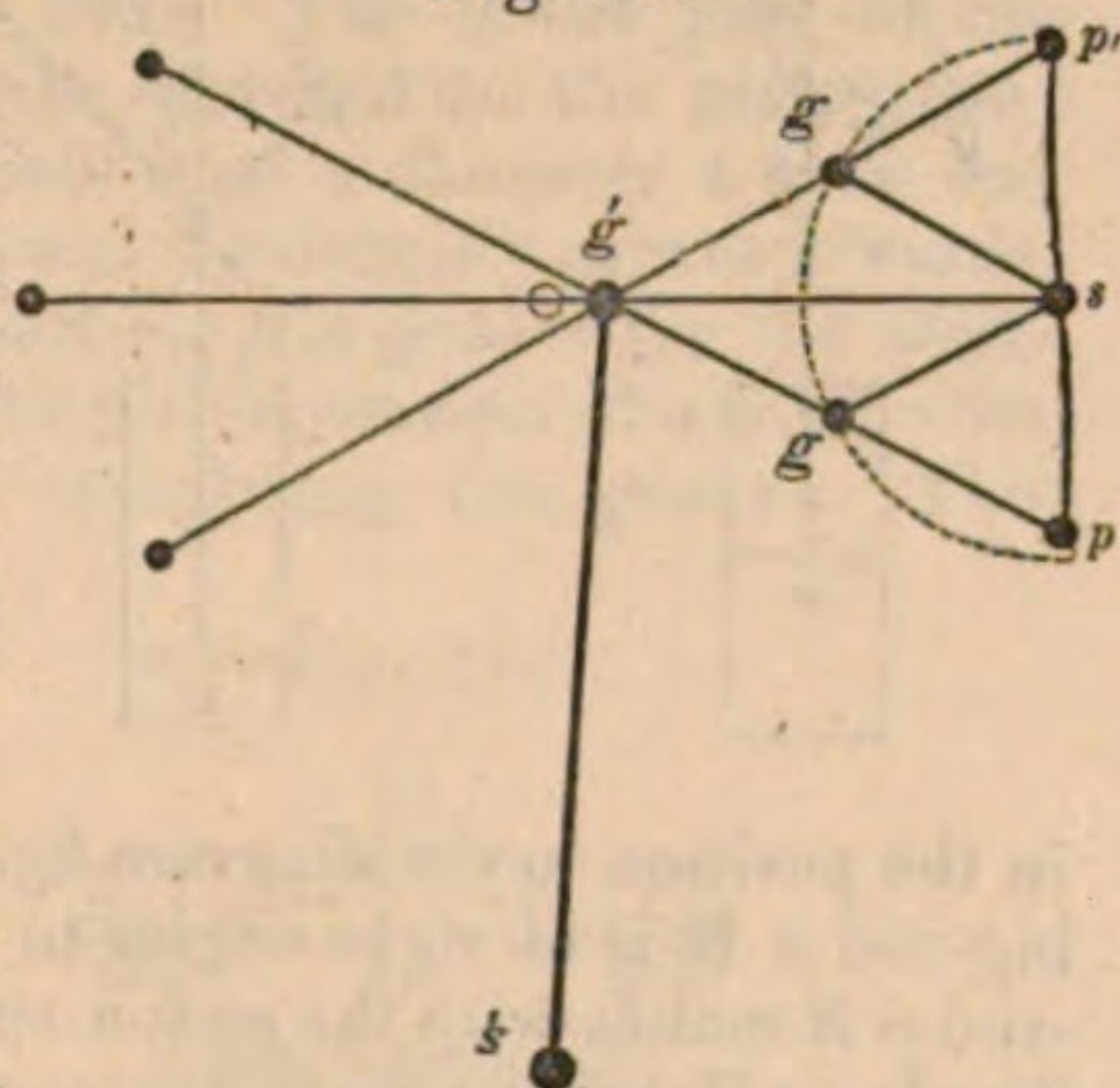
The pillar, which supports the beam or lever, instead of being fixed in an upright position, has a joint at the bottom, as will be seen in fig. 165, on which it and the beam and the crank-rod perform a joggling motion backwards and forwards during each stroke. The motion is of the

Fig. 165.



following nature. The point *s*, fig. 166, is fixed; so is *s'*; *sg* and *s'g'* are moveable bars; *pg* is $\frac{1}{2}$ of *pg'*. The point *g* describes a circle round *s*, and *g'* round *s'*: hence *p* describes the curve *psp'*, of the sixth order. The oscillation of the moving mass of the engine in alternate directions, with a sudden jolt at the end of the stroke, renders this a bad engine when made on a large scale; and it is obvious that the deviation of the piston-rod from the straight line is very great.

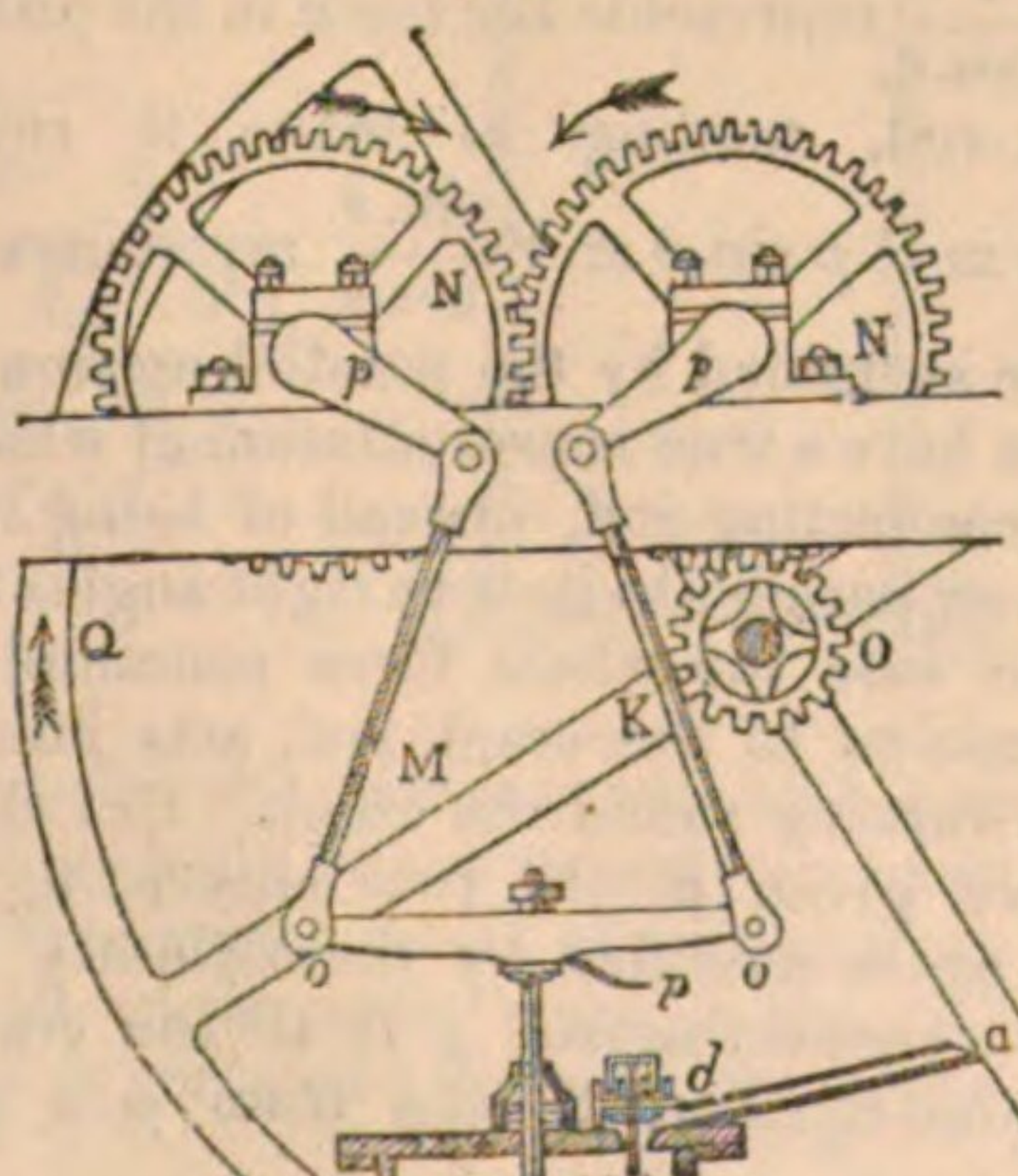
Fig. 166.



Cartwright's Parallel Motion.

A very elegant parallel motion was invented by the Rev. Mr Cartwright, and applied by him to the steam-engine so early

Fig. 167.



Steam-Engine.
Parallel Motions.

Or it may be thus modified. If the arc of a semicircle have one of its extremities placed in a given straight line, while it moves along a given fixed point, the other extremity of the arc will describe another straight line at right angles to the former. Let a semicircular round bar $y b x$, fig. 170, be allowed to slide through a fixed centre at s , the one end y sliding in a groove, or along a bar $s y$, then the point x will describe the perpendicular $s x^1$, a perfect straight line.

Fig. 17.

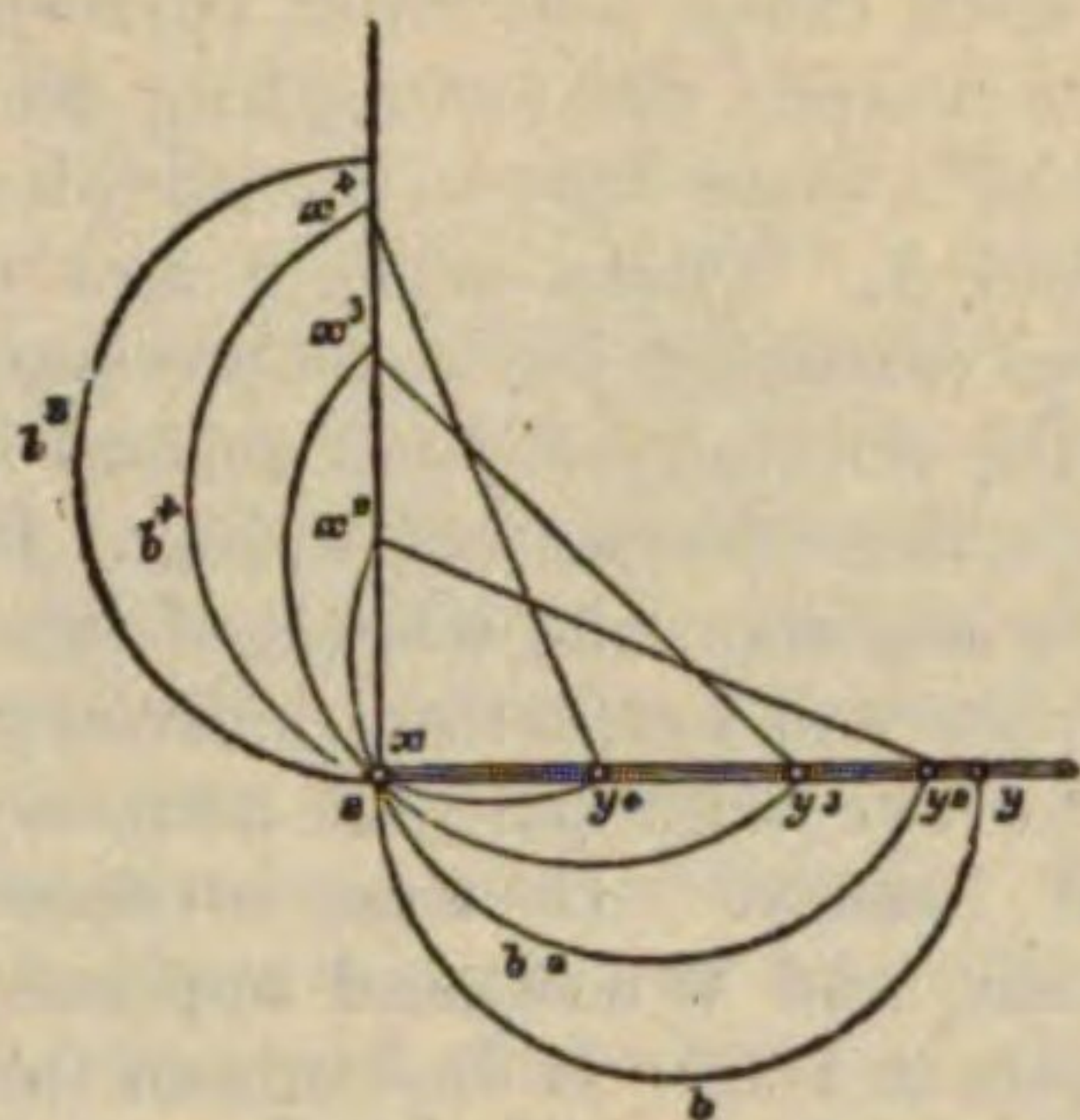


Fig. 171.

Fig. 172.

Fig. 173.

Fig. 174.

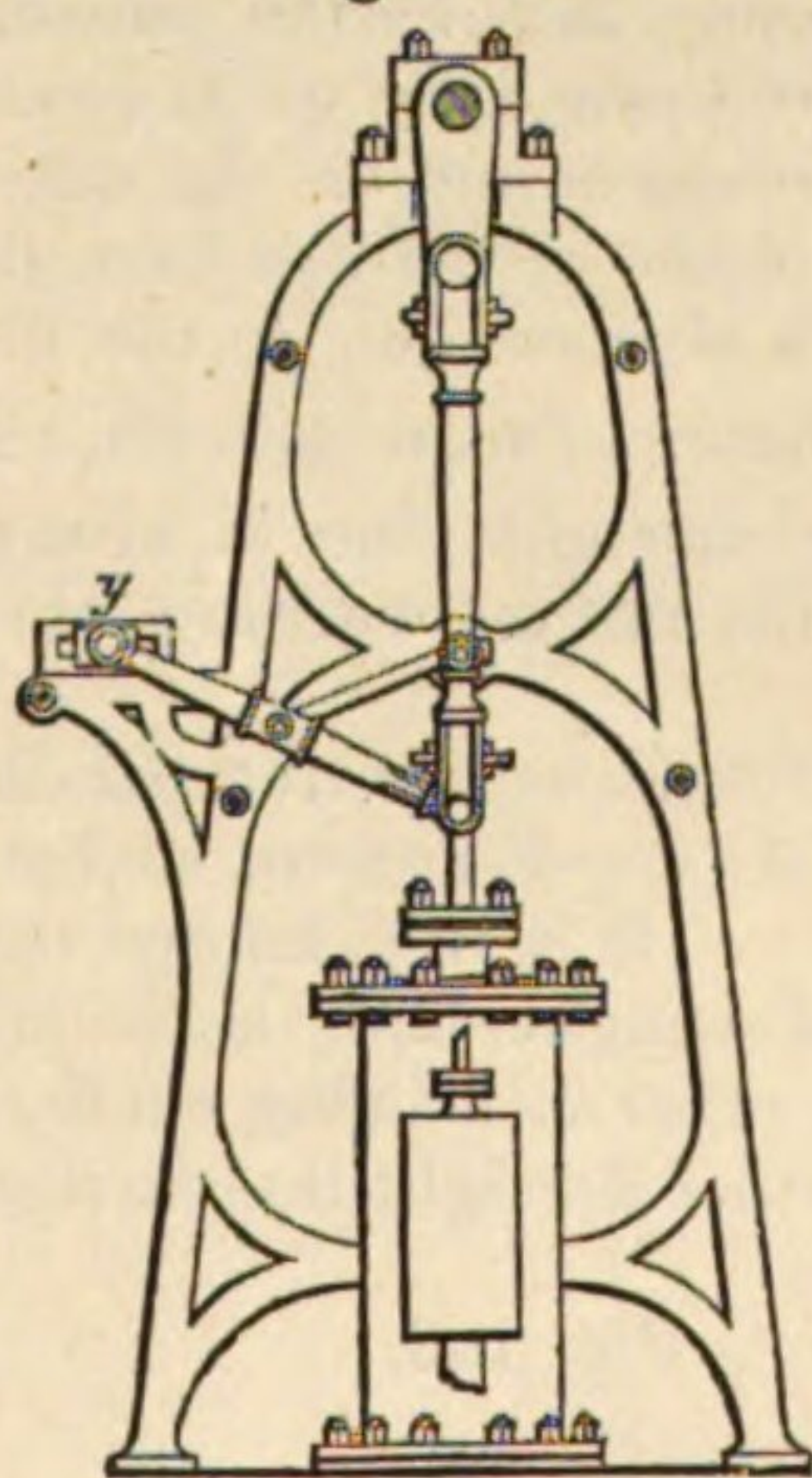
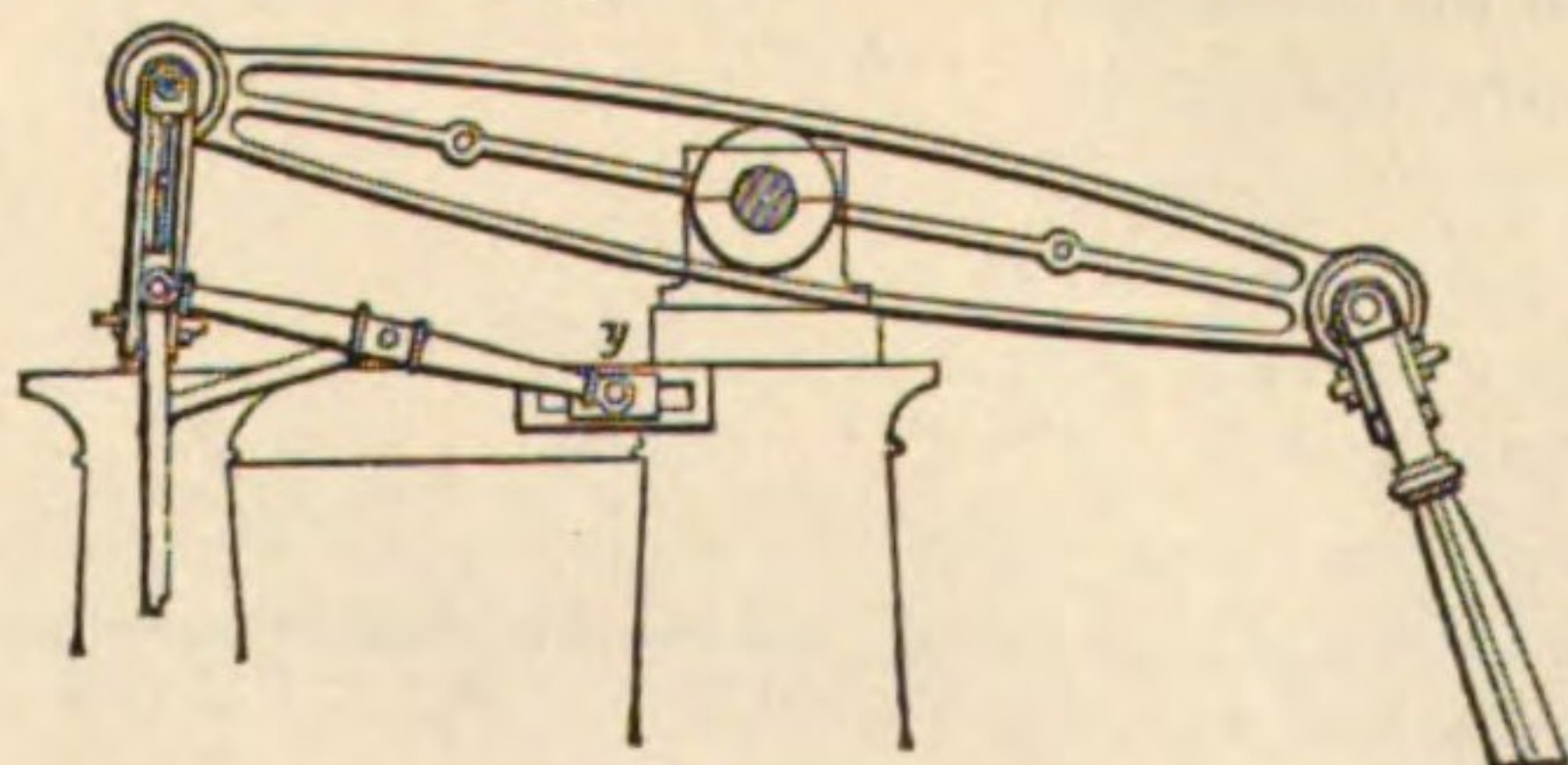


Fig 175.



To put this in practice in a form which shall not deviate widely from received forms of construction, is not difficult. The semicircular groove, and the semicircular bar, are not good constructive expedients. But if we take a radius bar $s g$, figs. 171, 172, 173, fixed at a centre s , so that its end g describes a circle freely round it; and if we take a rigid bar $p y$, of double the length of $s g$, and united to it at g , then the middle of $p y$ being thus constrained to move in the circle round s , we have only to permit y to slide freely in an horizontal groove, and the point p being carried up and down, will describe the straight line $p s p$. Fig. 174 shows the application of this motion to the simple engine, and fig. 175 to the beam engine.

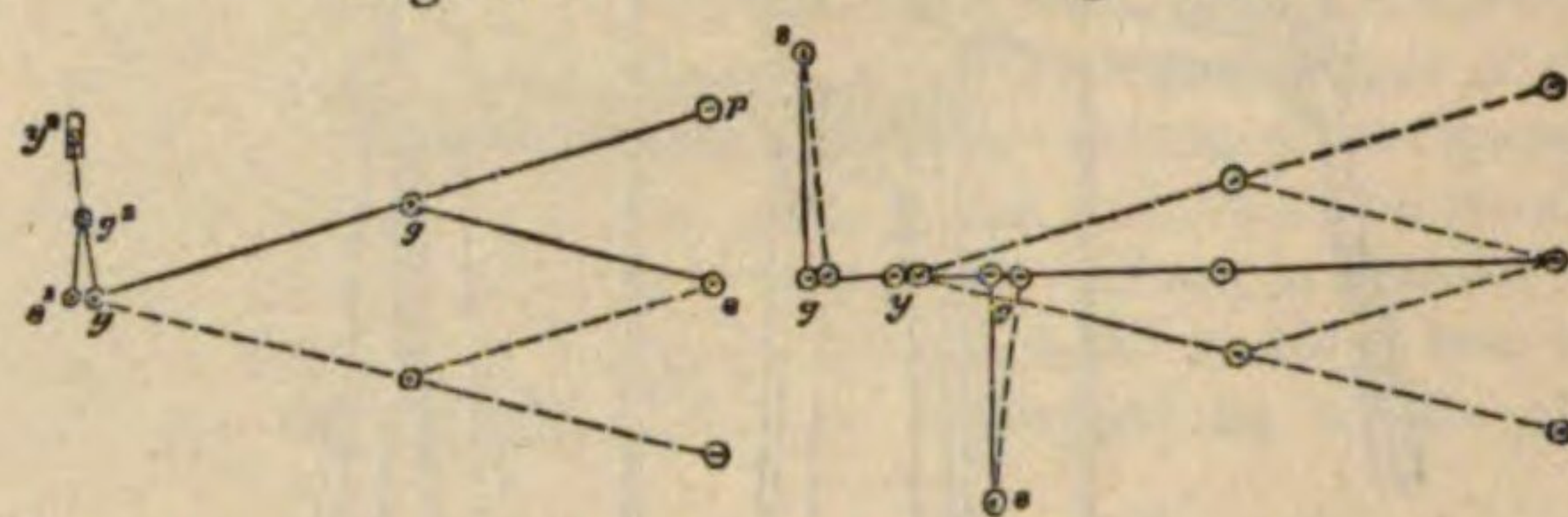
Mr Oldham of the Bank of England has shown us an application of this principle, of which he has made a model: he adds a refinement which diminishes the friction at y , while it introduces an infinitesimal error of the second degree. To the end y he has attached Watt's parallel motion, as represented in fig. 177; $s g g s$ being the radius bars, and $g y g$ the connecting link on a small scale, the point y is by this parallel motion guided in the hori-

zontal direction. Instead of this refinement, which only produces infinitesimal error, we propose, if it were re-

Steam-Engine.

Fig. 176.

Fig. 177.



Parallel Motions.

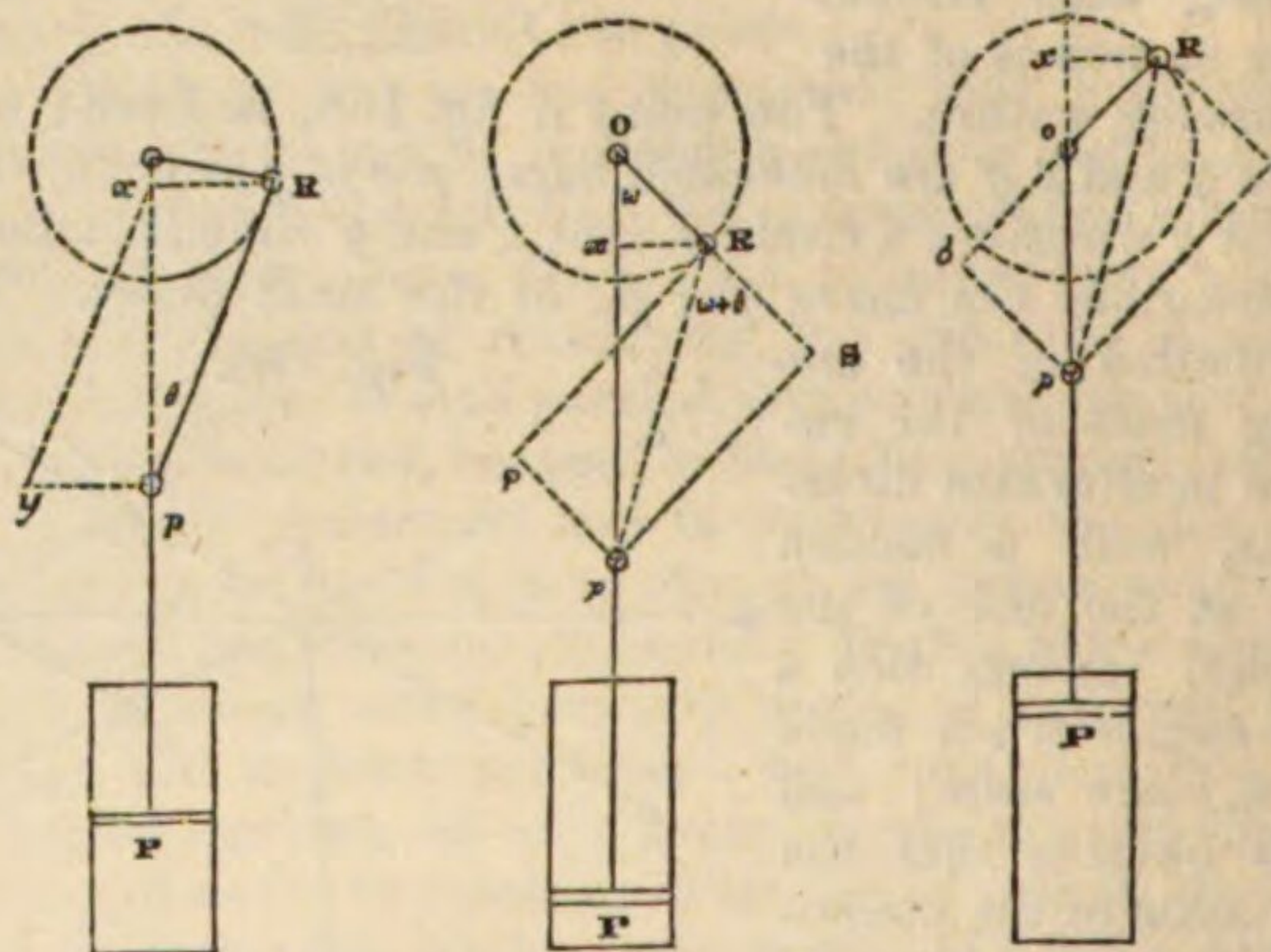
quired, to preserve the principle without error, and to introduce only infinitesimal friction. This we accomplish by placing a secondary geometrical motion like the primary one upon the point y , fig. 176, so that its motion may take place in a perfectly straight line. The effect of the friction will thus become an infinitesimal of the third order. These last refinements are, however, of a higher order than the degree of practical precision in the steam-engine usually requires.

Such is the mechanism which the obliquity of the direction between the connecting-rod, or link, renders necessary to prevent any of the motion, propagated through them, from being expended in producing oblique transverse motion in the top of the piston-rod. Still, however, the motion of the piston-rod is modified by transference in an oblique direction, and we have now to consider the nature of that modification. Suppose the crank $O R$ to be

Fig. 178.

Fig. 179.

Fig. 180.



in the position in the diagram fig. 178, where the connecting-rod $p R$ is at right angles to it, then the connecting-rod $p R$ makes with the piston-rod $P p$ an angle $O p R$ or θ . The force F therefore, acting along the piston-rod $P p$, being represented by the length of $p x$, and $x y$ and $p y$ being drawn parallel to $R p$ and $R x$, we see that the line $x y$ or $p R = \frac{F^1}{\cos. \theta}$ represents the force in the piston-rod along the crank-rod, tending to make it revolve, while $p y = R x = R p \sin. \theta = F \frac{\sin. \theta}{\cos. \theta}$ represents the amount of pressure sustained by the parallel motion.

Thus we have a true representation of what takes place when the connecting-rod, instead of being in a line with the piston, or parallel to it, is at right angles to the crank; and in this case the whole force communicated in this oblique position to the crank rod, acts immediately and entirely in turning round the crank. But at other points, such as are given in the two succeeding figures, the motion is again modified by the obliquity of the direction of the connecting-rod $p R$ to the crank $O R$. If $O R$ be prolonged to S , and from p a perpendicular

Steam-Engine.
Connect-
ing-rod.

dropped upon it, and the parallelogram $R p p \sigma$ completed, we shall have the diagonal force $p R$ resolved into $R \sigma$ and $R p$; whereof $R p$ alone tends to turn round the crank, $R \sigma$ producing only pressure towards the centre. In this case the angle $p R \sigma$ is equal to the two interior angles of the triangle $p R O$, that is to $\omega + \theta$, the sum of the angles of the connecting-rod and crank with the line of the piston. Hence the whole force in the connecting-rod becomes resolved into $p R \cos. (\omega + \theta)$ and the whole force of the steam on the piston-rod becomes on the extremity of the crank $F \frac{\cos. (\omega + \theta)}{\sin. \theta}$.

Details of the Piston.—The next elementary part of the steam-engine, upon which much of the efficiency of its operation depends, is the piston. Pistons were at first very rude implements for steam to work with. A large block of wood cut round to fit the inside of the cylinder, and driven very tight so as pretty nearly to fill up the cylinder, was considered a sufficient obstacle to resist the passage of the steam, until it had performed its duty, either of driving the piston from the bottom to the top, or from the top to the bottom of the cylinder. It next became usual to cover this piston with leather; but the heat of the steam soon dried up the leather, and deprived it of the requisite pliability. The next step was to make the piston of metal, like the piston of Otto Guericke's atmospheric engine, and then to make a groove around this piston, which was filled with bands of plaited hemp, now technically called a gaskin, so put together as to be spongy and elastic, and to interpose this elastic substance between the piston and cylinder, so that the hemp, yielding to the inequalities of the cylinder, should fill them up without permitting the steam to escape. This has been successfully used for a long period, and, where the cylinder is in good condition, used with advantage: and it is still very extensively employed. Instead of using a solid piston with a groove for the hempen packing, it was found better in practice to construct the piston as shown in fig. 182. The lower part of the piston is formed of a plate attached to the piston-rod; the under edge of this plate is of a diameter a little less than that of the cylinder, and it gradually curves inwards, so as to form the lower portion of a groove for the packing. The upper part of the piston consists of a plate with a similarly curved rim, completing the groove. This

forces the packing against the sides of the cylinder. The piston is represented *in situ* in figure 184.

The only fault of this hempen packing is its liability to wear out, and become rigid and unelastic. A plan was next adopted of protecting this hemp, and still using its elasticity. Around the piston, in front of the packing and enveloping it, two brass hoops, fig. 186, with slits in them, were placed, to protect it from contact with the cylinder. These slits allowed the hoops to enlarge and contract their diameter, in correspondence with the inequalities of the cylinder; while by the elasticity of the hemp, they were kept continually pressed out in contact with the surface. This simple metallic packing is re-presented as applied to the piston in figure 185.

Steam-Engine.
The
Piston.
Metallic
Packing.

Fig. 185.



Fig. 186.



A still more independent metallic packing is produced in the following manner, so as to dispense altogether with the elastic action of the hemp. Large metallic belts of considerable thickness are cast, so as to form solid rings, about a hundredth part greater in diameter than the inside of the cylinder they are to fit, and turned on a lathe truly cylindrical to that diameter. A small portion is then cut out of the circumference of each ring, so as to make them open hoops like those represented in the last figure; and the two open ends are then forcibly brought together, until their diameter is just such as to admit them into the cylinder, their ends being now in contact so as to form complete rings, and they are again placed in the lathe and turned truly cylindrical. By this arrangement it is brought about, that the elasticity of the rings continually urges them outwards, towards their original diameter, and so dispenses with the elasticity of the hemp, forming a packing wholly metallic. This is employed on a large scale by some of the very best engineers in this country, and is greatly to be recommended for its simplicity. Of course the break in the ring would allow steam to pass; but this is avoided either by interposing a metallic tongue at the break, or by using a number of rings, so that the break in one of them may be opposite to the sound portion of the other.

Another form of piston may be called the wedge metallic piston. The rings are cut into a number of parts, and are pressed upon the cylinder by wedges, which again are kept in their places by springs; and so it is supposed that a more perfect adaptation is gained of the parts of the ring to the cylinder. This is certainly the case; but the ring is much more complex than in the other form:—

Wedge
Piston.

Fig. 182.

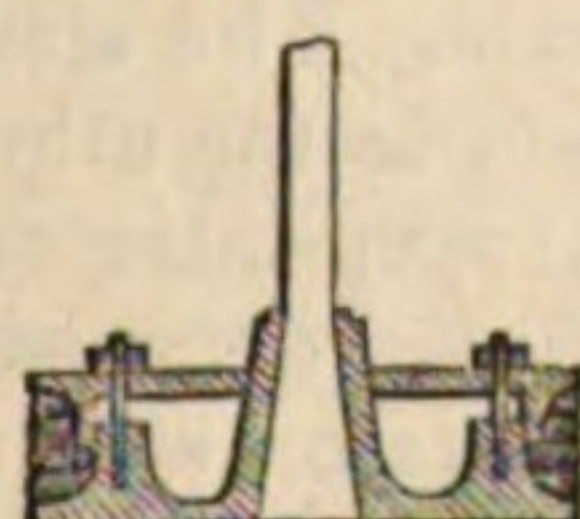


Fig. 184.

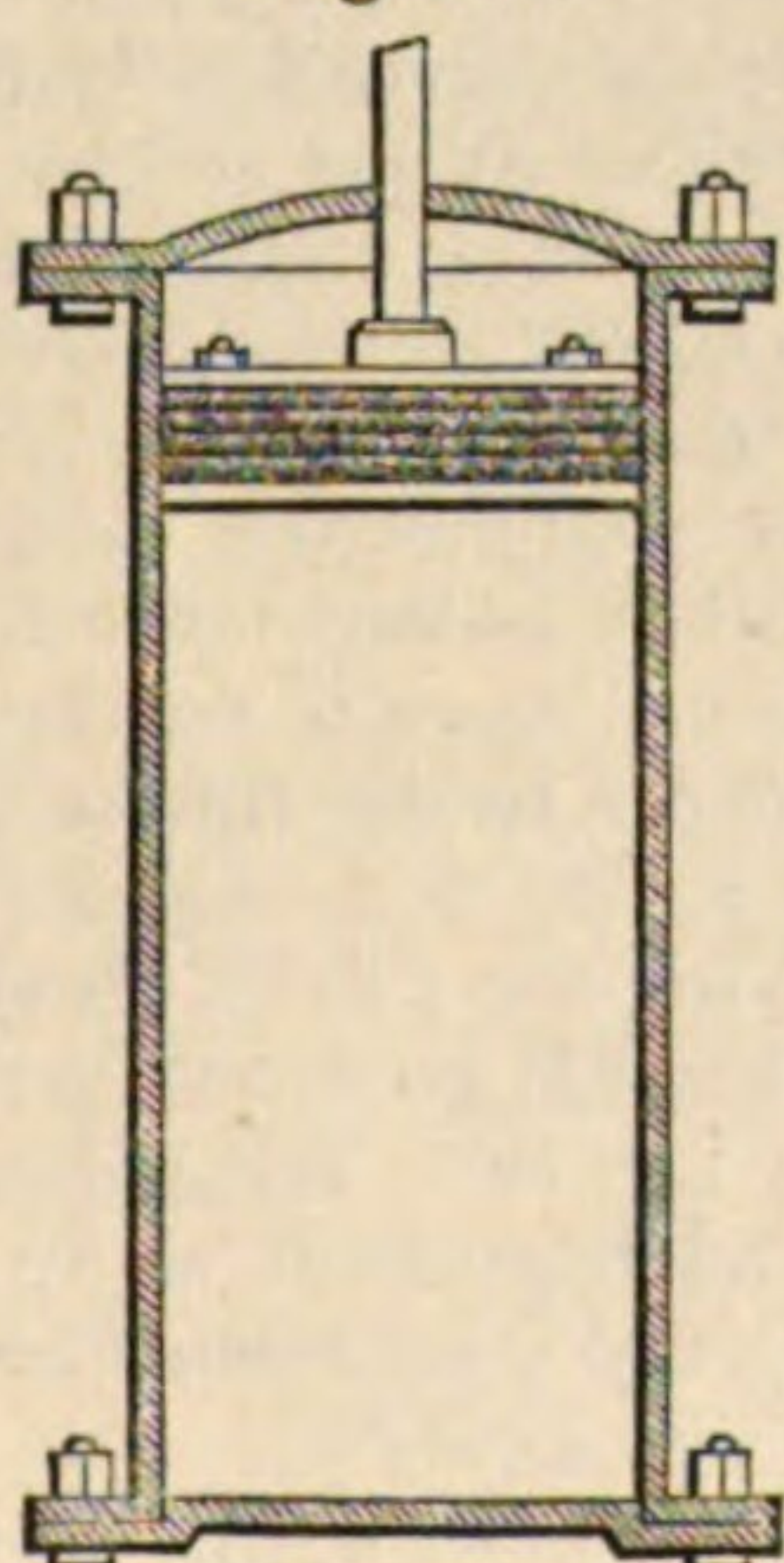
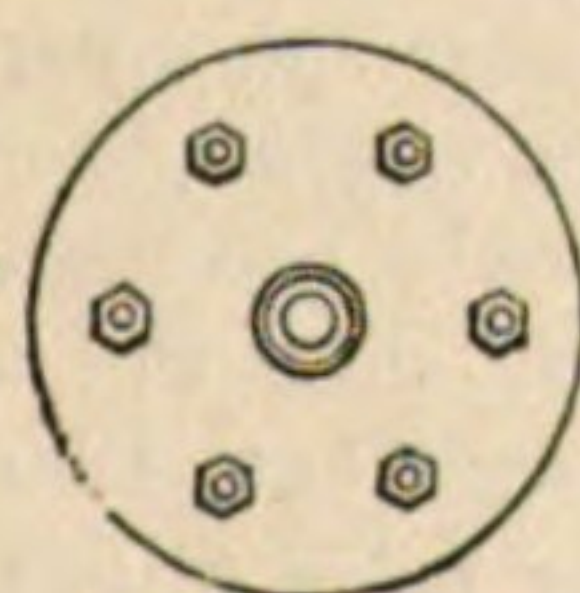


Fig. 183.



Figs. 187.

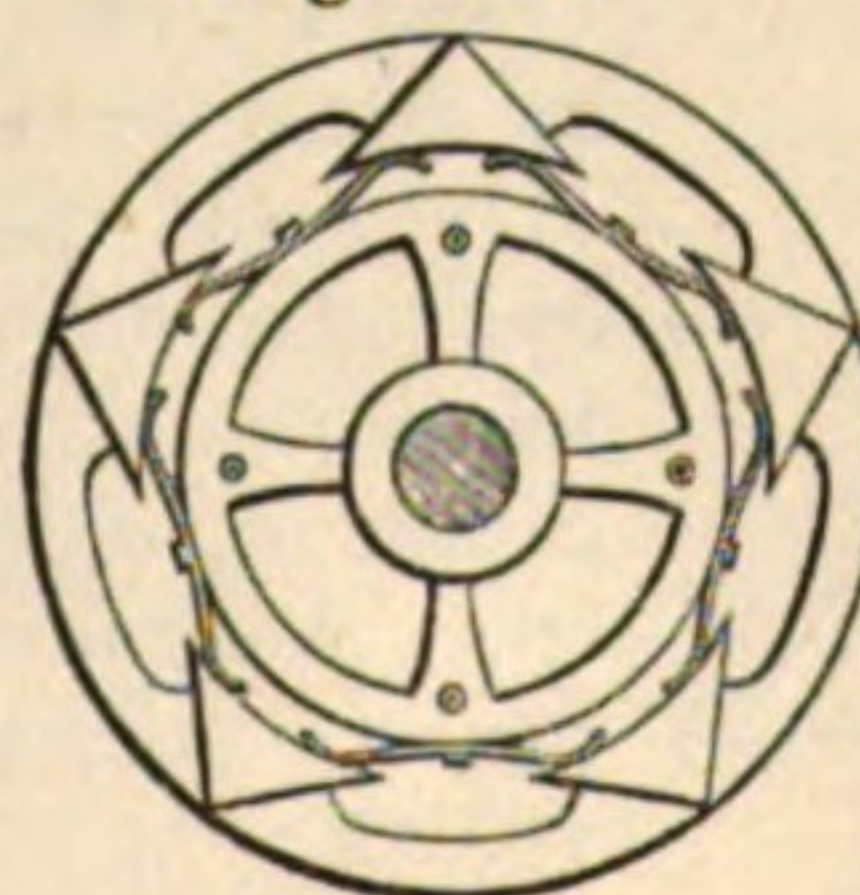
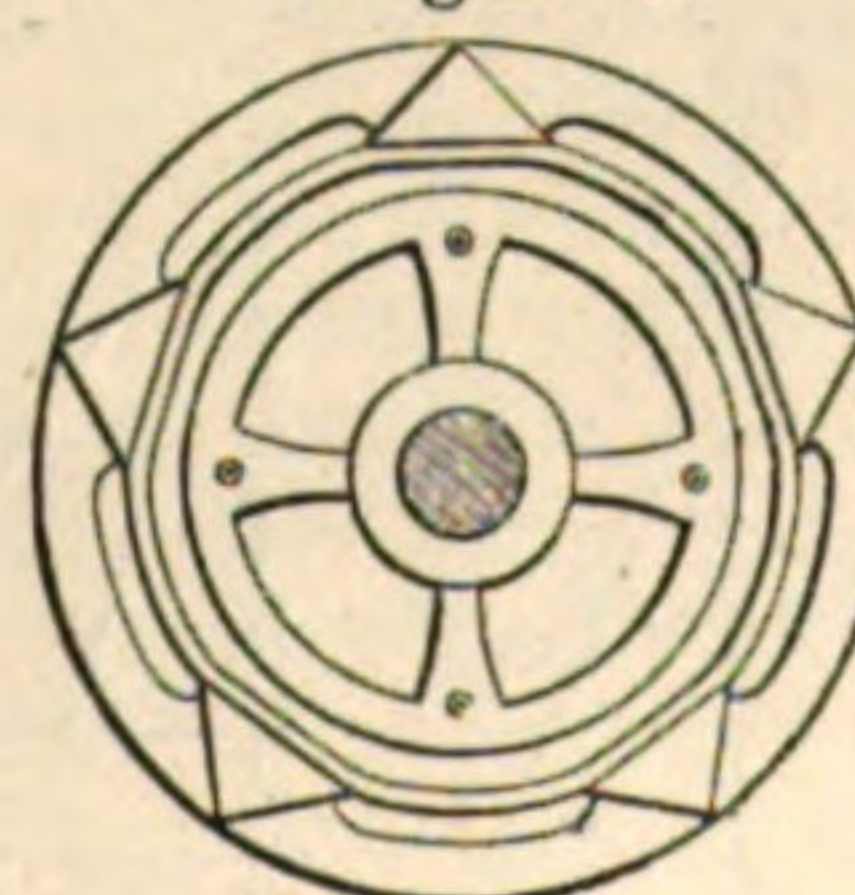


Fig. 188.



upper plate is called the piston-cover, and is attached to the lower plate or body of the piston by screws. In the groove are carried round bands of soft plaited hemp or gaskin, which fill up the cavity; and as the gaskin wears, the upper plate is screwed closer to the lower one, and

In fig. 187, wedges are shown to be inserted behind the rings, with springs behind them, forcing them outwards; and in the figure 188, a single elastic hoop is substituted for all those springs. Springs without wedges

Steam-Engine.

are also in very common use for metallic pistons with divided rings, double sets of rings being used, and the springs pressing directly on the segments of the metallic rings, as in figs. 189, 190.

Fig. 189.

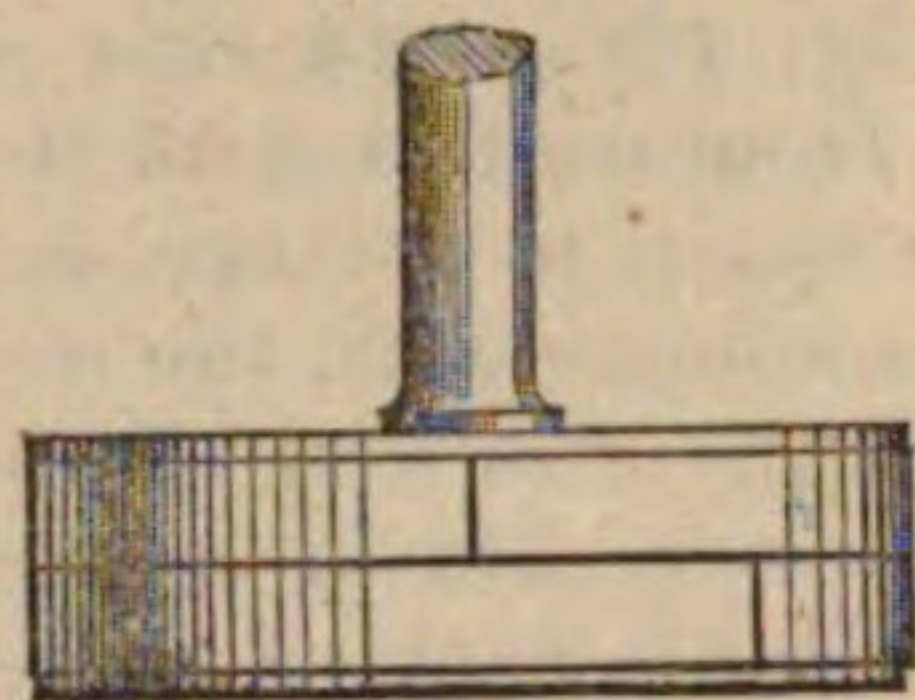
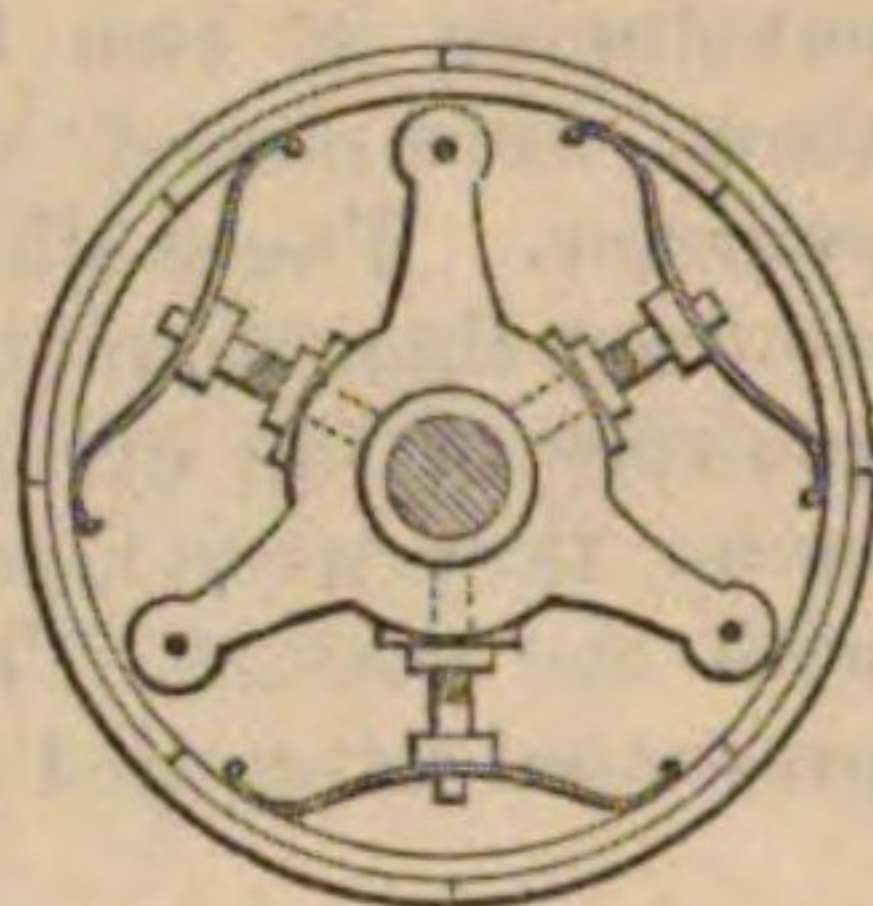


Fig. 190.



A stuffing-box is an apparatus used in immediate connexion with the piston. A simple aperture in the cylinder-cover to permit the passage of the piston-rod, as in fig. 191, could not be made steam-tight: so that to prevent the escape of steam, a stuffing-box has to be made use of. This consists of a box cast round the hole of the cylinder-cover, fig. 192, in which is laid, around the piston-rod and in contact with it, a large quantity of hempen packing. This packing is lubricated with oleaginous matter, and the ring, fig. 193, is then placed on the top of this mat-

The Stuffing-box.

Fig. 191,

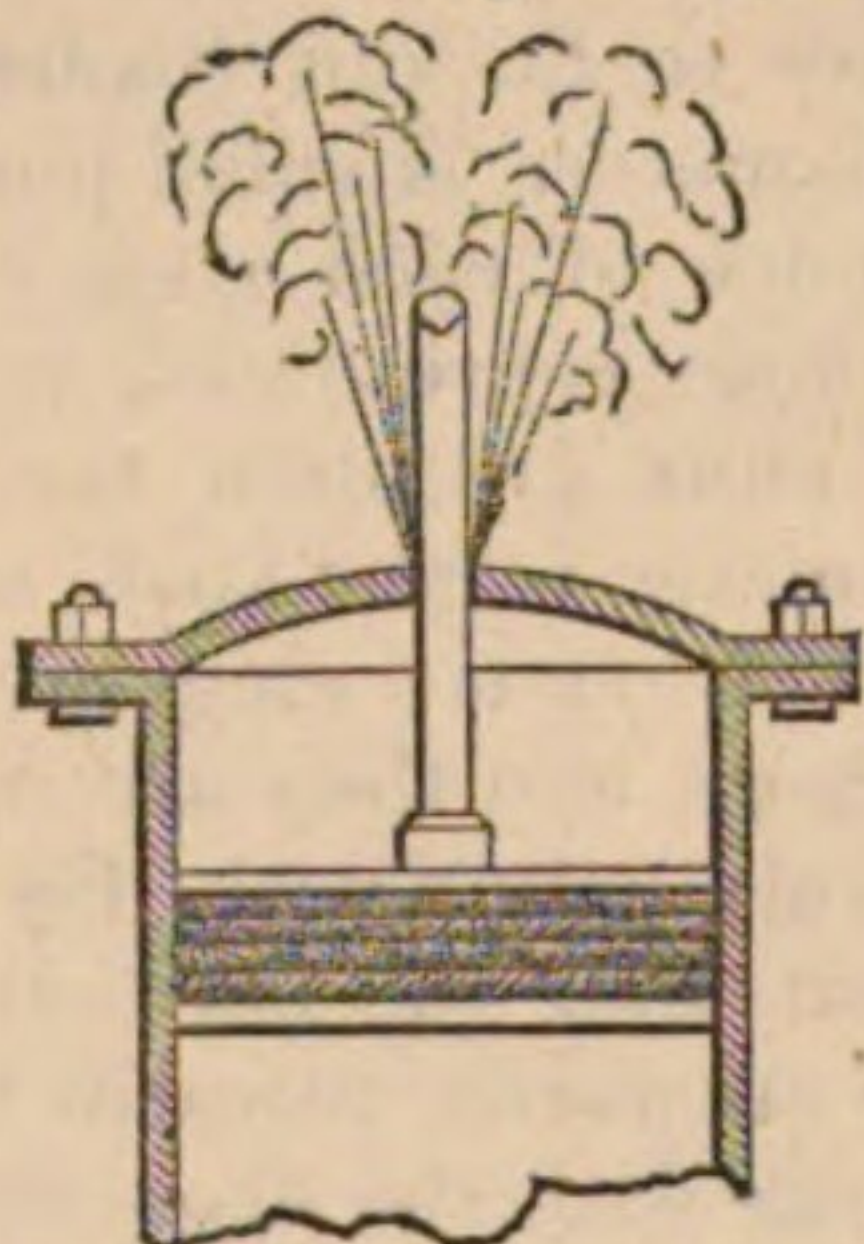


Fig. 192.



Fig. 193.



ter, and pressed hard down upon it by screws, so as to squeeze the stuffing into every crevice. Stuffing-boxes of this description are employed wherever it is necessary to pass a rod out of a vessel, or into it, without permitting the escape of the steam. Thus there is one at the entrance of each valve-rod into the steam-chest of the cylinder valves, and also, wherever a rod passes into the interior of a boiler.

The Steam-Engine Governor.

The governor is an appendage to a steam-engine, of much value in all its applications to the production of uniform revolving motion. It is merely a modification of an apparatus similar to the pendulum, and by which Huyghens once attempted to make a time-keeper instead of the common pendulum. If we suppose the axis A *x*, fig. 194, to revolve on its centre, and the ball B

Fig. 194.

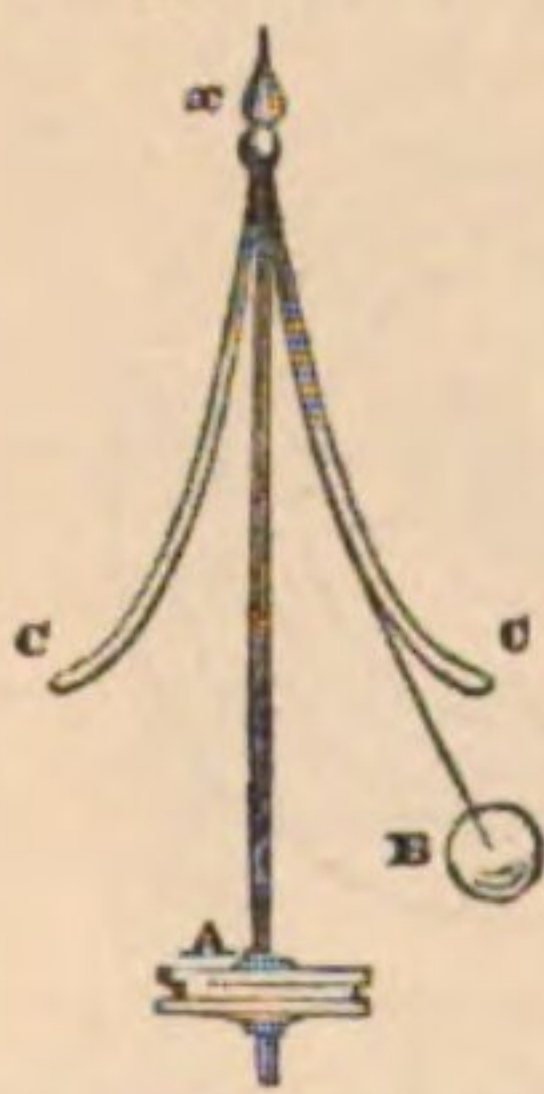
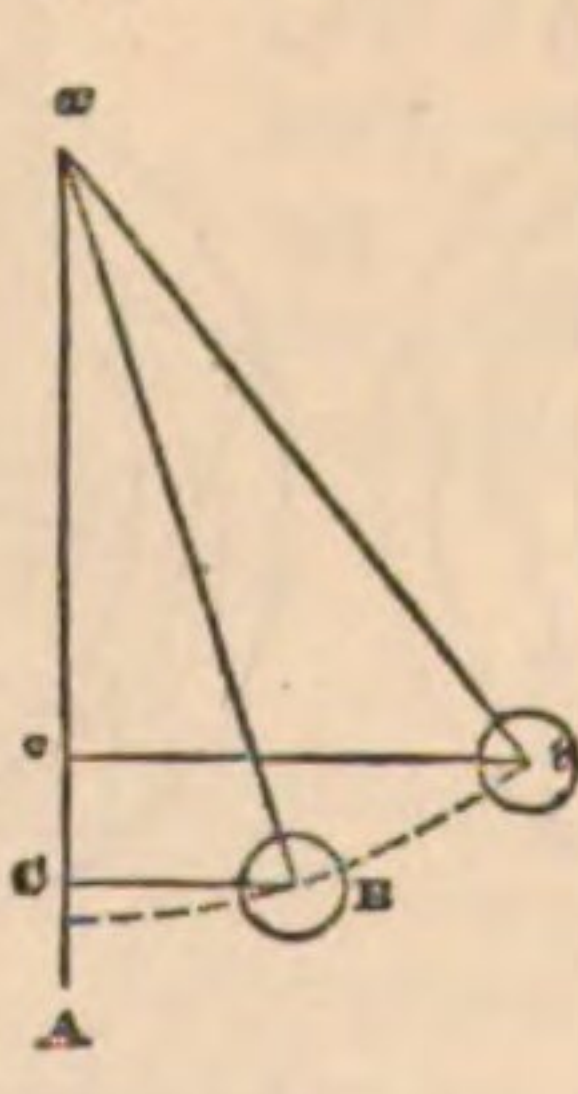


Fig. 195.



hung by a thread from *x*, two pieces of iron, *x* C and *x* C, being bent so as to form cheeks of a form called the cycloidal curve; then when the string B *x* comes in contact with the cheeks, it will perform each semi-revolution in the same time in which it performs two oscillations as a common pendulum; that is, if it be 39.1 inches from the centre of B to *x*, the pendulum will revolve once in two seconds. If, however, the ball B be suspended from *x* by a straight bar,

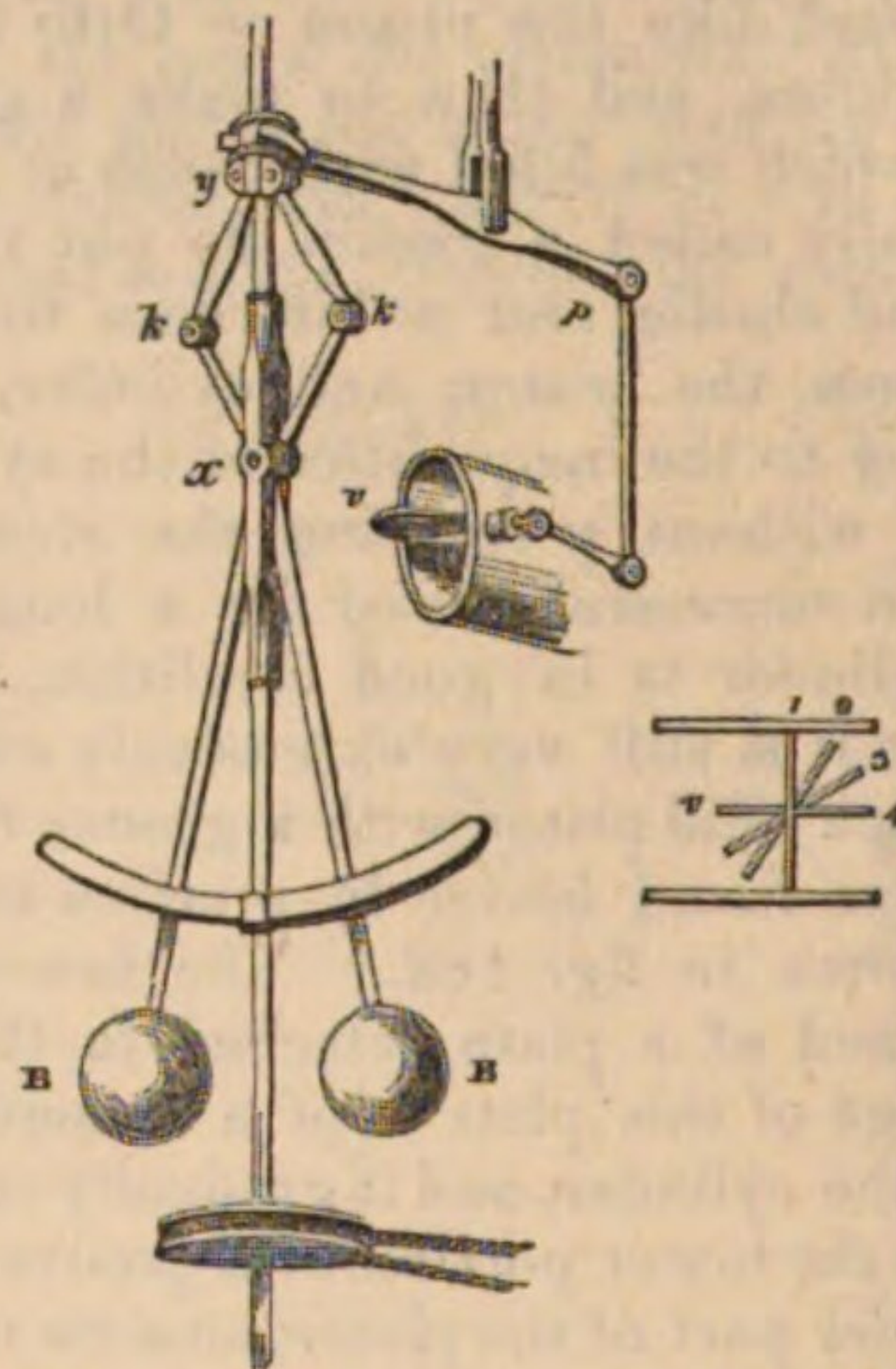
such as B *x* in the next figure, the line B *x* in deviating from A *x* will describe the circular arch A B, instead of a cycloid as formerly, and the time of oscillation will vary as the ball recedes from A, the revolutions being more rapid at *b* than at B. If in the position B, the line *x* C be 39.14 inches, then will the revolution be performed in two seconds, or at the rate of 30 revolutions per minute; while at *b* they will be performed in less time, and between B and A more slowly; and in general to find the height C *x* for any required number of revolutions, it is only necessary to find by the rules for calculating the rates of the pendulums of time-keepers, what length of pendulum will give double that number of beats per minute, and that is the desired height for C *x*. The rule for this purpose is easy. Divide the number 35226 by the square of the number of revolutions per minute, and the result is the height C *x*. Thus to find the length of A *x* for 30 revolutions per minute:—

$$30 \text{ squared} = 30 \times 30 = 900 \quad 35226 \div 900 = 39.14$$

required height = 39.14 inches.

The required regulation is effected in the following manner:—

Fig. 196.



The balls B B, fig. 196, are suspended by rigid bars from the centre *x*, and are prolonged to *k* *k*. These bars are joined by links, *k* *y* and *k* *y*, to a moveable socket *y*, which can slide up and down the axis. The straight lever *y* *p* is acted on at one end by *y*, and at the other it draws or pushes down or up the handle of a circular disc *v*, so as either to close it or open it to different degrees; this disc is in the steam-engine placed in connexion with the steam-pipe that supplies the cylinder, so that if the engine should at any instant move round too slowly, from having too much work to do, the balls will collapse, raise up *y*, and open *v* to the fullest extent, as at 4, in the small sectional figure to the right; 3 being the mean position; while, on the other hand, should the engine, from its work being taken off, go round too quickly, the balls would fly off from the axis, bring down *y*, close the valve to 2; or if it had happened, as by an accident, that the load was suddenly withdrawn, close the valve altogether, as at 1 in the side figure.

But the action of this governor is not always sufficiently delicate, its power of adjustment being somewhat slow. An improvement has been made upon it by Messrs Cheetham and Bailey, of Staley Bridge, in Lancashire, which renders its action much more rapid. On the centre of the throttle-valve, as the disc *v* in the steam-pipe is called, there is placed an iron tube, like a gun barrel, partially filled with mercury. When this tube

Steam-Engine.
Condensing Apparatus.

is held perfectly horizontal, an equal quantity of mercury lies in both ends; but, on the contrary, when the slightest inclination is given to either end, the mercury instantly preponderates to that lower end, and suddenly changes its inclination in either direction. In practice I have seen this work well.

Of Condensing Apparatus.—The parts of the condensing steam-engine which we have hitherto examined, are in all respects identical with those of the high-pressure steam-engine. The characteristic difference consists in the manner in which the steam is disposed of after having produced its effect, and in the apparatus required for the purpose. In the high-pressure steam-engine, the steam is discharged from the cylinder simply by allowing the entering steam to press the piston upon the outgoing steam, and force it through the eduction-pipe into the open air. Now, it requires considerable force to effect this; we know that the atmosphere must be pushed away before the steam with a force equal at least to 15 lbs. on each square inch of the surface of the pipe; and, therefore, this amount of the force of the steam, which is a balance for the air, that is, an atmosphere of steam, is consumed or thrown away in this employment. In the condensing steam-engine this atmosphere is saved. The steam is annihilated almost instantaneously. A vacuum is formed on one side of the piston by this annihilation, and the steam is allowed to employ that part of its force, which formerly was spent in the useless labour of forcing the steam into the air, in forcing the piston through the performance of useful labour.

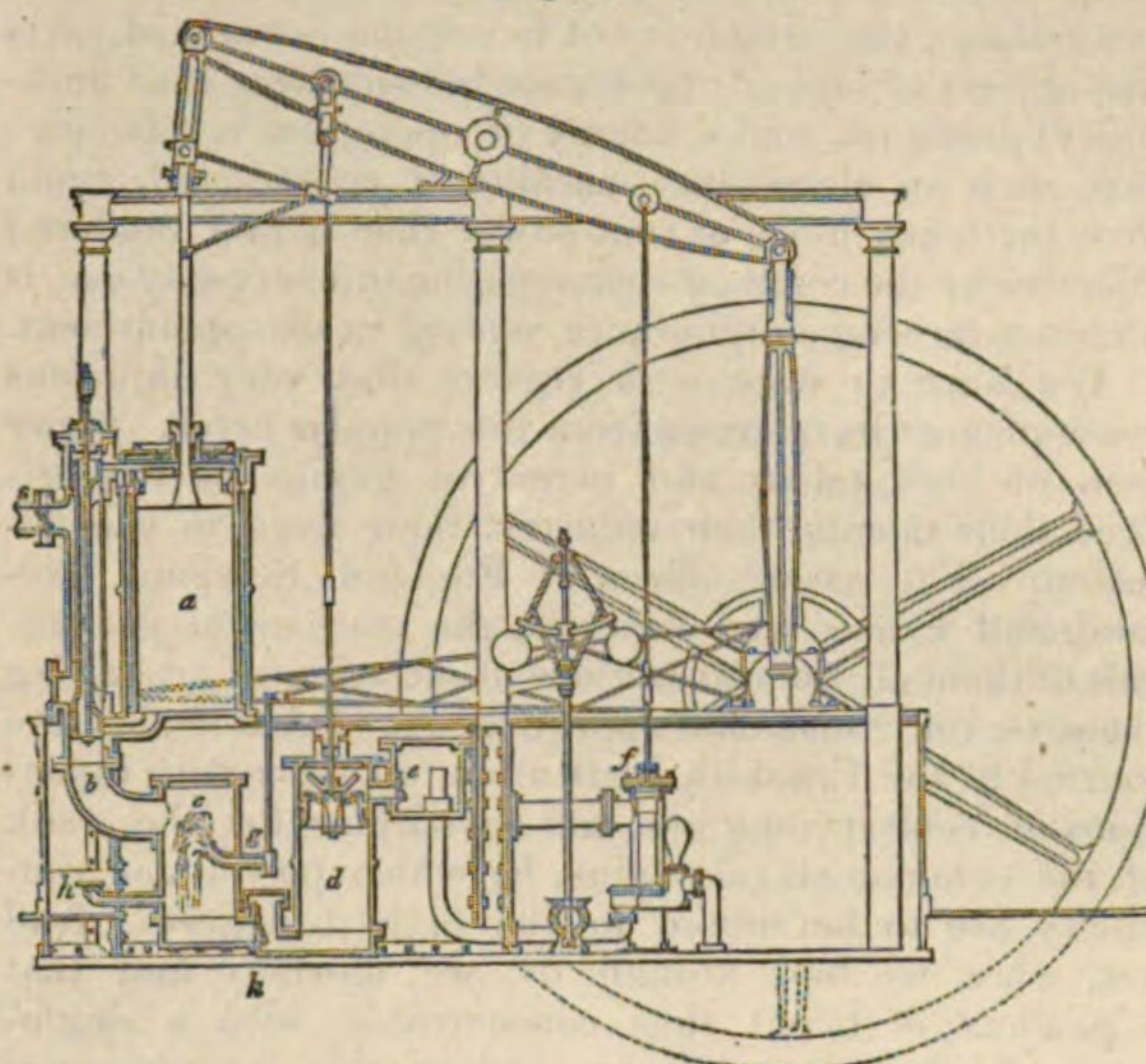
If, therefore, we take a high-pressure engine, such as we have already described, and if we desire to form it into a condensing steam-engine, we must add to it a large reservoir of cold water, named the cold well, such as is described in one of Watt's steam-engines, in the historical part of this article; and in this reservoir we must place a close vessel having an aperture or small pipe in it, from which a jet of water shall play and spread over the interior, so as to form a condenser, into which shall be conducted the eduction-pipe, by which the steam is led out of the cylinder. The quantity of cold water thrown into this vessel to cool it, will require to be six or eight times as much as is boiled off in the shape of steam. Attached to the condenser is a blow-through valve, opening outwardly, which allows the whole condenser, before starting the engine, to be filled with steam, so as to blow out at the valve all the air that may have previously got into it. The reader is referred to the historical part of this article for those parts in the description of Mr Watt's engine, and also to plates, and their descriptions of the parts of steam-engines at the end of the article.

It must already have occurred to the attentive reader, that such a condenser as has now been described could not act efficiently for any considerable time. On the contrary it would rapidly become filled with water; for it is plain that the jet of water entering the condenser will fill it up at last with water; and even were this not the case, it is plain that the whole steam which passes through the engine being turned back into water in the condenser, this water would accumulate and fill the condenser. This water must therefore by some expedient be removed out of the condenser without admitting the air. And again, it is well known that all water contains a large quantity of air mingled with it, and permanently retained in its pores, but which escapes from it the moment it is placed in a vacuum. Now this air would of itself accumulate rapidly, to such an extent as to fill up the vacuum of the condenser and render it inefficient. Air must therefore be removed out of the condenser, along with the accumulations of injection water, and the condensed water of the steam;

and therefore an air-pump must be provided, capable of removing air and water from the condenser. This air-pump is placed beside the condenser in the cold well, communicating with it by a foot-valve, which permits the air and water to go out and prevents their return, and delivering that air and water which it removes into another smaller reservoir, named the hot well, from the circumstance that the water withdrawn from the engine has been made warm by contact with the hot steam which it has condensed, and which it does not generally cool to a lower temperature than 80° or 90°.

These appendages of the condenser, the cold well, the injection-pipe, the air-pump, the hot well, the blow-through valve, the foot-valve, the delivering valve, &c., are represented in the following diagram, in a usual arrangement.

Fig. 181.



a is the cylinder, *b* the eduction-pipe, *c* the condenser, *h* the blow-through valve, *g* the injection cock and pipe, *k* the foot-valve, *d* the air-pump, *e* the hot well, *f* the cold-water pump.

The reader will find other arrangements of these parts in the plates and their descriptions. The air-pump is generally worked by the great beam of the steam-engine, as in the figure, and is about half the area and half the stroke of the cylinder of the engine.

The cold well requires a continual supply of water, either from a running stream, or to be forced up by a pump like that marked cold-water pump in the figure.

Dry condensation is a subject which has attracted much attention from machinists; that is to say, it has been considered very desirable to condense the steam without injecting water amongst it. Mr Watt originally condensed in this manner. He merely placed upright pipes among cold water, and letting the steam into them, allowed it to be condensed by simply coming in contact with the inside of these tubes, which thus formed a condenser. The introduction of a jet of cold water was thus avoided, the introduction of air along with the water was also avoided, and thus the air-pump had its duties much diminished. But the efficiency of the engine was found to be very materially impaired; for the instantaneous annihilation of the steam was not effected, in this process of mere surface condensation, in the efficient way in which it had been by the old system of injection by a *jet d'eau*.

ON THE ROTATORY STEAM-ENGINE.

The steam-engine being now most generally used in

Steam-Engine.
Condensing Apparatus.

Steam-
Engine.

our workshops, our manufactories, our steam-ships, and our locomotive engines, for the purpose of *turning round* certain axles or wheels with a continuous whirling or revolving motion, it has appeared to many the simplest, the most elementary, and the most appropriate manner of applying the moving power, that the steam should itself follow the wheel which it turns, round the circumference of its circle of gyration, and so it is supposed, by acting immediately and directly on the wheel to be turned round, produce the most powerful effect. In this way the action of the steam would be made to resemble the turning of a mill-wheel by the action of the water on the buckets of its rim; and the arrangements by which such an elementary mode of action might be brought about, form what is called a ROTATORY STEAM-ENGINE.

Fallacies
of the
Rotatory
Steam-
Engine.

That simplicity of form and of outline are essential to simplicity of action, and excellence of mechanical action, is a fallacy; that simplicity of figure and fewness of parts are objects of higher importance in machinery than durability, precision, and economy of operation, is a fallacy; that such an elementary machine, if constructed, could give forth any more of that power than is now rendered effective by the common steam-engine in every-day use, is a fallacy, arising in ignorance, ending in disappointment.

We have to state with regret, that very injurious consequences have arisen from this popular error. Many men of high talent and inventive genius have sacrificed their talents, their industry, their lives, to this delusion. The patent-offices of England, Scotland, Ireland, and France and America, the mechanical periodicals of them all, the transactions of societies for promoting the arts, the "machines approuvées par l'Académie," the journal of the Franklin Institution, all teem with inventions of rotatory engines, and substitutes for the crank of the common steam-engine, by which power and simplicity are to be united in the highest degree. And yet, when we look around us, we nowhere find that a phalanx of talent thus concentrated with a singleness of purpose, and an indomitable perseverance worthy a more hopeful object, has ever been successful in producing one form of mechanism to stand in competition with the common every-day reciprocating engine, with its crank and its fly-wheel and all its much condemned appendages. In this country alone a crowd of inventors have not only proceeded so far as to expend their ingenuity, labour, and money, in inventing and constructing machines of this class, and making them the subject of experiment, but more than a hundred of them have actually laid out in succession four or five hundred pounds a-piece in procuring the royal grant of monopoly for their valuable contrivances. We feel it, therefore, to be our duty to give a full and uncompromising exposure of the fallacies of the rotatory engine. We regard such a fallacy as a grievous obstruction to the advancement of the arts and the industry of Great Britain. It is to the prevalence

Prevalent
ignorance
of what
has already
been done.

of ignorance on this subject, that much of the misdirection of mechanical talent, in so far as it has been applied to the improvement of our prime movers, is to be attributed. Again and again, year after year, do we find the same machine invented and re-invented, and the same experiments repeated and the identical failures encountered. Of these failures, however, there is only a small number comparatively which comes before the public. Those alone which obtain patents are dragged into light; and of these we are only left to infer the subsequent failure, from the circumstance of discovering that their existence is recognised nowhere except in the parchments of the Patent-Office. It is indeed a matter of general regret, not limited to the subject of rotatory engines, that false pride should prevent men from publishing the results of such experiments as may not be

perfectly successful in accomplishing the objects originally intended. It should be recollected, that, as evidence of the truth or falsehood of some great principle, no experiment is valueless, if simply and faithfully described; and that, if it do not serve as a signal-post to point the way to truth, it may at least prove useful as a beacon to warn from the path of error. It is to unsuccessful experiments that we owe many of our most valuable scientific discoveries. The failure of an attempt to make a sucking pump more than 33 feet long led to an acquaintance with the doctrine of atmospheric pressure, and opened a new field of research to the genius of Galilei, Torricelli, and Boyle; and Sir Humphrey Davy is reported, on an occasion where he was shown a dexterously manipulated experiment, to have exclaimed, "I thank God I was not made a dexterous manipulator, for the most important of my discoveries have been suggested to me by failures." Thus we find that the record of error may often prove a contribution to truth; and the man who is sufficiently unselfish to impart to others the benefit of such experience, is the disinterested friend of science. Had all the failures of the rotatory engine been publicly recorded, that avenue of misdirected effort would long ago have been closed.

Our present object is to bring together, and place under the eye of the reader, all that has been done upon this subject, the attempts that have been made, and the failures of those attempts. We shall thus show that the attempts at a successful rotatory steam-engine which are every day produced, are mere repetitions of experiments which have long ago been tried in circumstances precisely the same, and have long ago hopelessly failed and been abandoned: that these attempts were made in circumstances that were well suited to ensure their success, had success been possible. Let it be recollected that the only office performed by machinery, is the transmission of power from an animal or element, and never the creation of power. It can modify motion in direction, velocity, and force, so as to expend itself in one manner rather than another, but it can never create motion or generate power. This is true, or all the experience of the laws of matter which has been obtained since the use of inductive philosophy is false. Solid matter may obey force and modify it, but can never create power. The only enquiry to be made, therefore, in regard to any engine is this: when force is applied to the machine, whether the force of steam or any other, does it turn all the force of the agent to a useful purpose, without further diminution than is occasioned by necessary friction and resistance of the air, and the least possible loss of power by transmission? When steam bursts a boiler, or water overturns the embankment of a reservoir, the power of heat and of gravity produces its full effect; but it is not a useful effect. The object of a machine is to expend it parsimoniously in rendering the greatest portion of its effect useful. The only question entertained is, which form of engine is best calculated for converting the power of steam to a useful purpose, so as to do so with the smallest diminution in its quantity?

The common, or reciprocating steam-engine, is distinguished from the rotatory steam-engine by the nature of certain parts of its mechanism, which convey the motion of the steam to the machinery which is to be moved: these are a piston-rod and crank. Now, it is owing to a radical misconception of the nature of this elementary machine, the crank, that innumerable schemes have been devised for the production of circular motion, without the intervention of the crank, either by giving to the steam itself an immediate circular action, or by the substitution of some other less elementary mechanism between the reciprocating piston and the revolving axis, as the means

Steam-
Engine.

Rotatory
Engines.

General
functions
of a ma-
chine.

Steam-Engine.
Rotatory Engine.

of producing its rotation. In the most common form of the rotatory engine, the cylinder, piston-rod, and cranked axle are superseded by a cylinder, valve, stop, and axis. In the same way as a mill-wheel is compelled to move in a circle, either by the direct action of water or wind upon it, so is the drum, or wheel, with valves, fans, or other projections on its circumference, urged round by the force of the steam, and, enclosed in an outer cylinder, or case, gives revolution to an axis to which it is attached. This direct rotatory action of the steam will, it is imagined, give out the effect of the steam more powerfully, uniformly, and economically, than the common mode of reciprocating action when converted by the crank into revolution.

Classification.

Rotatory engines may be arranged, according to their manner of action, into four classes:—

- 1st CLASS—Rotatory engines of simple emission.
- 2d CLASS—Rotatory engines of medial effect.
- 3d CLASS—Rotatory engines of hydrostatical reaction.
- 4th CLASS—Rotatory engines of the revolving piston.

As closely connected with the rotatory engines, in the fallacy which has given rise to most of them, we may add a series of inventions, forming a

5th CLASS—Revolving mechanism substituted for the crank.

Rotatory Engines of the First Class.

CLASS I.—The rotatory engine of simple emission forms the earliest, as well as the most rude and elementary, method of giving motion to mechanism by the escape of vapour or steam. It is described by Hero of Alexandria, in his *Pneumatica*, upwards of 120 years before the Christian era, and depends for its effect upon the same principle which gives to a rocket its career, and makes a fire-wheel revolve in displaying its beautiful lights. In these, as in all instances where fire or steam or any fluid or gas is generated in a chamber, from which it is permitted to issue with violence, it will, in its exit, drive the vessel from which it issues away from it in the opposite direction; and it is, in fact, merely an application of the principle of recoil, where the gas generated by the explosion of the powder urges the ball outwards in one direction, and forces the breech of the gun backwards in the opposite one. The same recoil is felt in all cases of simple emission of a fluid from a reservoir; and if it be so arranged that water, steam, air, or the gaseous product of gunpowder, rushes out of a chamber through the arms of a revolving wheel, the openings of escape being properly directed, the recoil will urge round the wheel, and we shall have a revolving engine of simple emission. By availing himself of this principle, the machinist of Alexandria produced a working engine, merely by heating a vessel containing water and air, and allowing the vapour to rush from two opposite orifices, at the end of two arms proceeding from a sphere, which the emission was employed to move.

Instead of using the principle of recoil, the force of steam, issuing with violence as we see it from the mouth of a kettle or boiler, may be directed upon the naves of a wheel so as to blow them round; and thus we have a second variety in the manner of converting the simple issue of steam into a moving power. This second species of the rotatory steam-engine of simple emission was invented by Branca, 1629. Since that time the engines of this class have been frequently re-invented and slightly modified.

Rotatory Engines of the First Class.

The theory of machines of simple emission has been frequently and fully investigated; and the result is, that there is no possibility of obtaining by simple emission, in the most favourable circumstances imaginable, more than one-half of the whole power of the steam, so as to make it available to useful mechanical effect. The other half is wasted in giving off its impulsion to the air, or is expended in a current equally unavailing.

Practical experience corroborates the predictions of theory. Smeaton and Pelectan have made the machine of simple issue the subject of careful experiment:—3 parts out of 11, 8 parts out of 27, and 2 parts out of 5, are the highest measures of the useful effect that it has been found practicable to attain; and by no possible improvement can more than one-half of the whole power be turned to a useful effect.

CLASS II.—Rotatory engines of medial effect are those which do not immediately give revolution to an axis, by the action of steam upon the wheel, but have a medium of communication between the power and the effect, which medium is the direct agent in circular motion. This class of engines will be well understood, by taking as its type any simple steam-machine, such as Savary's or Newcomen's, used for raising water; which water, by falling on the floats of a common mill-wheel, will then give rotatory motion to it. The engine of Savary raises water by pressing directly on its surface; and it is only necessary to allow this water to fall on a wheel, and it will be made to revolve, and form an engine of the second class.

A variety of this class has been invented, of which the Fire-wheel of Amontons is a type. The steam pushes water through certain channels that form the arms of the wheel, from a set of chambers on one side of the wheel, to a corresponding set of chambers on the opposite, and thus the side filled with water preponderates over the other, and the wheel revolves. The water being constantly driven off by the steam from a given side of the wheel to that opposite, uniform revolution is the result of the weight of the water. In this case, although steam is the agent, water is the means of communicating the rotatory motion.

Solids have also been made the medium of effecting rotation in this manner. Weights of solid matter, in the form of pistons, have been transferred by the force of steam to a considerable distance from the centre on one side of a wheel, and drawn nearer to it on the other side, so as, by bringing about a continual preponderance of one side, to effect a revolution. Watt and De Witty have designed arrangements of mechanism of this nature.

In this class of engines the loss of effect is manifest; for it is necessary that the steam, in order to produce the circular motion, shall give out its force in setting the medium in motion, and in overcoming the very great resistance of the liquid in all the pipes and passages and valves, through which it is transmitted to alternate sides of the wheel in every revolution. The force thus subtracted from useful effect, is power lost.

In those which move weights from and towards the circumference, there are mere groups of reciprocating pistons, without cranks, and partaking of the defects to be explained in Class V. In fact, in the engines of Watt and De Witty of this class, we have a number of reciprocating engines ranged round a wheel to do the work of one.

In the case of the fluid medium we have not only a loss of all the power expended in moving the medium itself, but also the additional loss of effect encountered in all modes hitherto adopted for applying a fluid to the rotation of a wheel; a loss, in the best examples ever presented in practice, amounting of itself to more than $\frac{1}{6}$ th part of the power.

CLASS III.—Engines of hydrostatical reaction are more effective than either of the former classes. As invented by Watt, in 1796, this species of engine consisted of steam-vessels, in the form of hollow rings or circular channels, with proper inlets and outlets for the steam, mounted on horizontal axles, like the wheels and buckets of a water-mill, and wholly immersed in some fluid.

Steam-Engine.

Rotatory Engines of the Second Class.

Rotatory Engines of the Third Class.

Steam-Engine.
Rotatory Engine.

These tubular wheels were made of iron, six feet in diameter, and the reaction of mercury was employed to give revolution to them. The engine moved, but was found to be inefficient, and was abandoned, although it had been tried in very favourable circumstances. The principle of action is this. Steam is admitted into a circular channel, or chamber, on the circumference of a wheel. This chamber is partially filled with some liquid; the pressure of the steam is expended in pushing the mercury in one direction, and the end of the chamber in the opposite way; so that, while the liquid is thus forced out of the chamber, the chamber is by an equal force pushed away from the liquid. The wheel is thus moved round. It is apparent that a part of the force is employed in propelling the wheel, and the remainder is expended in overcoming the resistance of the liquid of reaction, and expelling it from the chambers, which remainder is a large portion of the power withdrawn from useful effect.

Rotatory Engines of the Fourth Class.

CLASS IV.—Rotatory engines of the revolving piston are constructed on a much better principle, and hold out much fairer prospects of successful competition with those of the reciprocating piston, than any of the species of the first three classes that have been already considered. In these classes the steam is not confined in rigid vessels, but its action is expended in producing currents in fluids, and expending motion in medial effects, which are useless. This is not the case in the steam-engine of the revolving piston. The steam is confined in a close and rigid chamber, and acts only on solid inflexible surfaces, and escapes along confined passages, so that its full effect may be obtained in useful work. Abstractly considered, it is an engine capable of giving out the full power of the steam, and, therefore, may fairly be imagined to come into competition with the ordinary reciprocating crank engine. The objections to it are entirely of a practical nature, and regard the engine, not in its abstract mathematical form, but as a machine made of destructible matter—of matter imperfectly elastic—of surfaces offering resistance to motion—of matter obeying the known laws of motion and rest. These objections are not the less valid that they are of a sensible and tangible, rather than a speculative description. But, as a natural consequence of the more plausible deceptions held out by this species than by any of the three preceding ones, it has followed that the fallacies of this class have been more widely seductive than the others; and many eminent mechanics have been led astray by them. The fallacy of this class of engines we shall expose in conjunction with the next class, as the same misconceptions lie, to a considerable extent, at the root of both.

Rotatory Mechanism of the Fifth Class.

CLASS V.—Revolving mechanism substituted for the crank of the common steam-engine, for the purpose of obtaining from the reciprocating piston a rotatory effect otherwise than by the crank, and in a better manner than by the crank, forms a class of inventions involving fallacies similar to those in which the revolving piston has originated. These two may therefore be considered together.

Although the name of Watt has been included in the list of inventors of substitutes for the crank, it should be observed that he was only driven to the invention of a substitute by the circumstance of a patent having been previously obtained for the crank in its simple form; and that he abandoned his beautiful, but more complex, mechanism on the instant that the elementary crank was released from the fetters of monopoly. It is due also to his memory to say, that the sun and planet wheel, which he substituted for the crank, is a disguised crank, possessing all the valuable properties, excepting simplicity and smallness of friction, which give to the crank its present eminence as a mean of obtaining rotatory effect. It is remarkable that the fallacies regarding the now universally employed crank were coeval with its first sug-

gestion as the vehicle of rotative steam power. John Stewart, in describing his mechanism for this purpose, in the Philosophical Transactions, 1777, observes that "the crank or winch is a mode of obtaining the circular motion which naturally occurs in theory, but in practice it would be impossible, from the nature of the motion of the engine, which depends on the force of the steam, and cannot be ascertained in its length; and, therefore, on the first variation, the machine would either be broke to pieces or turned back." Mr Smeaton agrees with Mr Stewart on the inapplicability of the crank; but adduces another objection, "That great loss would be incurred by the absolute stop of the whole mass of moving parts as often as the direction of the motion is changed, and that although a heavy fly-wheel might be applied to regulate the motion, it would be a great encumbrance to the mill." In such phrase of evil omen was it thus confidently predicted that the simple means now in every-day use for the communication of steam power to revolving machinery would either be attended with great loss, be very desultory in its action, or altogether break the machine to pieces. At that time, however, the crank was not in use; but the very same objections are still urged by those who have, every day, before them the practical confutation of their assertions.

I. In the abstract and purely theoretical view of the subject, it can be shown that the present mode of applying the steam possesses none of the disadvantages, and that the rotatory mode possesses none of the superiority attributed to it.

In making the comparison between the rotating and reciprocating piston, let it be supposed that the vessels containing the steam are equally rigid, equally perfect in their form, and are equally divested of friction, and that there shall have been obtained for the steam a *point d'appui* as satisfactory in the case of the rotatory, as that which the reciprocating engine possesses in the ends of the cylinder; then, upon this hypothetical condition, neither engine will excel the other, each will move over a space with a power and velocity proportioned to the steam which it makes use of, and that engine will do most work which uses the greatest quantity of steam.

The great fundamental principle in the construction of machinery is, that the work done depends in quantity only upon the quantity and velocity of the power applied, and not at all upon the form of the machine; in other words, that a machine has no power, either of consuming or creating motive power; that it can only transmit it; that it can only modify it to suit particular purposes; and that what it loses in pressure it will gain in velocity; this is on the supposition, of course, that the machine is perfectly well made, without friction, and without permitting the escape and waste of power in some effect not conducive to the end in view. Setting out, then, from this great fundamental principle of virtual velocities, we might satisfy ourselves with asserting the truth we now wish to establish as a simple self-evident deduction from it, and conclude that from this great principle of virtual velocities there could not possibly be loss of power by the crank steam-engine.

This summary process would not, however, satisfy the enquirer or inventor who has taken the erroneous view of the subject, unless he were given to understand how this great doctrine may be made to bear on the peculiar difficulties of the case. He will return upon us with the question—"How is it that, in the common crank, we are able to show that, at two given points in its revolution, the position is such that an infinite power would produce no effect at all; that there are only two instants of time in which the force and its effect are equal; and that, at every other point, the pressure given out by the steam to the crank is less than the original pressure of

Steam-Engine.
Rotatory Engine.

Fallacies concerning the Crank.

Theoretical View of the subject

Fundamental principle of *vis viva*.

Unsatisfactory nature of the General Conclusion.

Steam-Engine.
Rotatory Engines.

the steam on the piston? How is this inconsistency to be reconciled?" We think it right to give a direct answer to this question, because a considerable authority, Mr Tredgold, has committed a grievous error in reporting, and apparently demonstrating, that the rotatory and crank engines actually differ in theory in the proportion of 3 to 2 — the proportion being against the rotatory engine; whereas, if they be not equal, our whole system of mechanics since the time of Galileo has been resting on a fallacy.

Let it be recollected, then, that at the two extremes of the line of centres the greatest loss is said to take place. Now, here the fact is, that it is impossible there can be loss of power, for there is no power at all exerted; there is no steam in action: it is forgotten that, at this point, the communication which supplies the steam from the boiler has been cut off. The steam on one side of the piston having done its work, only waits to be released from the chamber, and escapes on the instant of the opening of the eduction-valve, and at the same instant is in the act of being permitted to enter on the opposite side, for reversing the motion. At these points, therefore, all application of force has ceased, and arrangements are making for reversing the motion; and, as no power is applied, none can be lost.

In regard to the remaining points of the circle, at which it is said that power is lost, it is easy to show that the velocity imparted to the crank is such as to be an exact equivalent to the force which is apparently lost. The following table presents the results of very accurate calculations of power and velocity, showing that the velocity at a given point in the circle is increased exactly in the same ratio as the force or pressure is diminished, so as at all times to present the same dynamical equivalent. The table extends from one neutral point to the other neutral point of the orbit of the crank, comprehending a semicircle divided into ten equal parts. The first column indicates the point in the semicircle at which the force and velocity are estimated; the next column shows the percentage of the direct force of the steam on the piston, which is given out in pressure upon the crank of the engine; and the last column, the velocity given out at each point.

Place of the crank.	Per centage of power given out in pressure.	Relative velocity.
0°	0.00	Infinite.
18°	30.90	3.236
36°	58.78	1.701
54°	80.90	1.236
72°	95.11	1.051
90°	100.00	1.000
108°	95.11	1.051
126°	80.90	1.236
144°	58.78	1.701
162°	30.90	3.236
180°	0.00	Infinite.

From this table it is evident that when we take note, as we must do in every correct estimate of power, both of force and velocity, the crank has at each point the equivalent in greater velocity for less force.

The numbers in the second column also represent the velocity of the piston in relation to the crank, so that when the velocity of the crank is uniform, the velocity of the piston, or the steam consumed, which is proportional to its velocity, is in the exact ratio of the pressure on the crank.

The last consideration which we shall submit upon this part of the subject is, that if the average of the pressures on the crank be taken for every point of its orbit, it will amount to about 63.3 per cent. for the whole circumference of the circle. Now, as the same circumference of the

orbit of the crank is greater than the stroke of the piston in the cylinder, the whole space described in a given time by the crank is greater than the whole space described by the piston, also in proportion of 3.1416 to 2; so that if we combine the greater length of the whole orbit with the force on it, we shall have an exact equivalent to the greater force on the piston moved through a smaller space.

The error of Mr Tredgold lies, not in his estimate of the effect of the crank, but in his estimate of the effect of the steam in the rotatory engine. By a strange oversight, he gives a statement of its power as much over the truth as that of the crank is generally stated under the truth. We admit that, in the first abstract view of the subject, the rotatory is theoretically a perfectly efficient propagator of power, and we have merely designed to show that in theory the crank has not the faults usually attributed to it, and is also a perfect machine. We shall by and by show what the considerations are by which the impracticability of the rotatory scheme is exposed.

It appears, therefore, that the power of steam is by no means disadvantageously applied through the medium of the crank in the ordinary way, because, 1. the velocity of the crank is in the inverse ratio of the pressure upon it; 2. because the mean pressure on the crank during the whole revolution is less than the pressure on the piston, only in the proportion in which the whole space moved over by the latter is less than the space described by the former, so that the whole effect is equal to the whole power; 3. because the steam is not at all expended at the neutral points, and because its expenditure is at every point exactly proportioned to the pressure which it gives out, the velocity of the piston being in that ratio. In theory, therefore, the ordinary crank possesses no inferiority to the rotatory machine, as an engine for applying the power of steam to revolving machinery.

II. In a practical point of view, it may be shown, that the rotatory steam-engine is greatly inferior to the common reciprocating crank-engine in simplicity of parts, easy construction, cheapness, amount of friction, compactness, precision and uniformity of work, and durability and economy in use; and that it does not possess any of the peculiar applicability that has been attributed to it, to the great purposes of inland navigation and railway transport.

1. Simplicity. — A little unfairness is sometimes inadvertently used by inventors of rotatory engines, in making comparisons with their machines and the common crank-engine; they select the large beam-engine with all its conveniences and appendages, and compare it with the simplest form of the rotatory engine; but in justice we may be allowed to take the simplest form of both. Now, there is a simple form of engine used both in America and in this country, of the oscillating species as it is called, and this species of reciprocating engine consists only of the following parts:—cylinder, piston, and cranked axle; there are no valves or further mechanism of any kind, so that where simplicity is the first great requisite, this kind may be used with advantage. The rotatory engine of the most simple species must have its drum, diaphragm, piston, and axle.

If we take those forms of the rotatory engine which require valve-gear, air-pump, condenser, force-pumps, &c., such appendages will have no advantage of any kind, in either form; but in working the pumps which are themselves reciprocating, the reciprocating engine will have the advantage of more direct, immediate, and simple action; for in the rotatory engine additional mechanism is necessary to convert the revolving motion into one calculated for reciprocating pumps.

Steam-Engine.
Rotatory Engines.

Practical View of the Rotatory and the Common Crank Engine.

Steam-Engine.
Rotatory Engine.
Practical View.

2. In ease of construction the simple form of reciprocating engines incomparably excels the rotatory. To possess equal powers, the rotatory drum would require to be of much larger diameter than the reciprocating cylinder; and the difficulty of construction increases in a high ratio with the diameter. The diaphragm is also a sliding or revolving piece of mechanism, whose rubbing surfaces require the greatest precision of workmanship. The revolving piston is also a practical problem of the greatest difficulty, and one which has never been satisfactorily solved; for if it be rectangular with plane surfaces, it is scarcely possible to make its surfaces steam tight; and if it be a circular and revolving piston, its surface and that of the drum become surfaces of double curvature, and the difficulty is then prodigiously increased. The metallic piston of the common steam-engine is the most perfect and most simple piece of mechanism, which can be made by a very ordinary workman, and which, if imperfectly fitted, will, in the progress of doing its work, become of itself every day more and more perfect. An editor of a well-known practical journal, although a believer in the rotatory engine, speaking of one of its simplest forms is compelled to admit, "that there being no mode described of making the parts of the engine steam-tight by packing, they must be all made so by accurate workmanship and grinding, the expense of which, in the outset and in repairs, would certainly be too considerable to allow it to come into competition with other steam-engines of a more common and practicable construction." His admission is equally applicable and fatal to all the forms of the engine.

3. The cheapness and first cost of the engine, will result from the two former points of inferiority, and will be further shown, from those which follow, to be greatly and necessarily in favour of the common engine. Not only are the parts, from their nature, more easy of construction, but the extent of polished surface will be shown to be much greater in the rotatory, than in the reciprocating engine.

4. The quantity of surface exposed to friction is greater in the rotatory engine. Let it be recollected that, in the rotatory engine, the piston describes the semi-circumference of the circle, while the piston of the reciprocating engine is describing the diameter of it. Let it also be recollected, that the reciprocating piston passes back through the returning stroke, over the very same surface through which it formerly descended, while the rotatory piston necessarily revolves over a new surface, forming the other semi-circumference of its orbit. Let it also be recollected, that the form of the reciprocating cylinder may be so proportioned, that it may have a minimum of surface, while the length of the circuit of the rotatory piston prevents the possibility of giving it a proportion to the radius of the piston by which this object would be attained; for it would be equivalent to making a circle whose diameter should be equal to its circumference, which is impossible. It is impossible, therefore, that the friction can ever be as small in the rotatory as in the reciprocating engine.

5. Compactness.—It follows in like manner, that the bulk and space occupied by the rotatory engine must be greater than in the reciprocating engine; for in the one case the piston must describe the circumference of a circle, whose diameter is greater than twice the radius of the piston, and in the other case it is only necessary that the piston pass through the diameter of it.

6. In precision and uniformity of working, its inferiority will be rendered manifest under head III., when the peculiarities of the crank are explained.

7. In durability and economy in the wear and tear of ordinary working, the rotatory must, from certain ele-

ments in its constitution, be necessarily far inferior to the common engine. It contains in the very nature of its action, elements of speedy destruction and expensive and frequent repairs, so that it can never become an economical engine. Before proceeding, however, to demonstrate the cause of this inferiority, the fact of this inferiority, as existing in all previous engines, we shall adduce from the unwilling evidence of a friend to rotatory engines. Speaking of Mr Halliday's engine, he says that, "the extreme accuracy and nice fitting of parts necessary for it, will make it very difficult to execute and very easily deranged. Rotatory steam-engines possess considerable advantages both as to speed and economy of power, and would therefore be preferable if they could be made to work as well for a continuance, and be as easily kept in good order as common alternating steam-engines; but from their being so very seldom used, we apprehend that this is very far from being the case with any of them at present, and that the production of a rotatory steam-engine possessed of these necessary qualities, is still an object of research." So far the Editor of the Repertory of Arts, in testimony that the rotatory steam-engine *never has* been made to work durably and economically; we now go on to show that it *never can*.

It is essential to the durability of a machine that its parts should wear uniformly, and that, if possible, the mere process of wearing should make them fit each other more closely. This is pre-eminently true of the piston and cylinder of a common reciprocating steam-engine. Its piston, cylinder, and valves fit more closely as they wear, and are worn with perfect uniformity, so as not to require repair until, by long working, the whole thickness of matter in action shall at length have been consumed. This is the perfection of mechanism, and is admirably exemplified in the metallic piston of a steam-engine, which, working night and day, will require no repair of any kind until, after a long period of years, the whole strength of the metallic rings shall have been consumed.

In the very nature of the rotatory piston, this uniformity of friction, this increasing adaptation of surfaces, this permanence of the best working condition is impossible. A common reciprocating steam-engine attains its best working condition after it has wrought for some years; but a rotatory steam-engine, if it have been brought by care and precision in workmanship to a state of high finish and perfect accuracy, so as to work well for a day, commences from that moment a rapid course of deterioration, every succeeding degree of which accelerates the progress of decay; a decay which can only be retarded by continual, laborious, and expensive repairs. The following considerations may render obvious the nature of the elements of self-deterioration in the constitution of a rotatory steam-engine.

Suppose two perfectly flat plates of polished metal perfectly round to be laid one upon the other, so as exactly to coincide at every point; let the undermost rest upon a table, and let the uppermost be so made as to turn round on an axis while in contact with the other, and let a rapid motion be communicated to the uppermost; let us consider what the result of the attrition of one of these upon the other will be: will they wear equally, so as to remain in a state of mutual adaptation, or will they not? Experience furnishes us with a reply that exactly quadrates with a reasonable expectation: they will not wear equally, they will not retain their form, they will not remain flat; they will wear away most rapidly at the circumference, and wear open there while they are quite close at the centre. Let it be considered that the outer edge performs a larger circuit than a part nearer to the centre; that, therefore, since all

Steam-Engine.
Rotatory Engine.
Practical View.

Steam-Engine.
Rotatory Engine.
Practical View.

the parts revolve in the same time, those nearer to the circumference move with greater velocity than those towards the centre; that the attrition is consequently most rapid at the circumference, and diminishes uniformly towards the centre of the plates; and it necessarily follows, that towards the edges the plates must commence an immediate and rapid waste, while the centre remains uninjured. This result is established as matter of experience. It is a circumstance that has caused the failure of many beautiful inventions. It is the reason why conical bearings have been universally abandoned for cylindrical ones; and it is the reason why a most beautiful class of inventions has been totally useless to the improvement of the common steam-engine; we refer to the revolving valves invented by Oliver Evans and by Murray, but now universally abandoned, in spite of their simplicity and original cheapness, on account of this inequality in the attrition of flat surfaces revolving round a centre.

The application of the result of this illustrative experiment to the subject in question is abundantly obvious. The rotatory piston is necessarily and inevitably of this nature. Performing a circuit round a centre, different portions of the bearing surfaces subjected to pressure, and necessarily in contact and requiring to be steam-tight, revolve at unequal distances from the centre, and therefore with unequal velocities; hence the circumferential surfaces, under this excessive attrition, wear more rapidly, and become unfit for use long before the central parts have suffered any sensible effect. It is to this difference of velocity and of attrition, arising from the necessary circumstance of motion round a centre, which renders it impossible to keep the rotatory engine in a working condition with advantage, and from which it follows that each day's work renders the engine less fit for the duty of the succeeding day.

8. The peculiar applicability of the rotatory form of steam-engine to the purposes of steam navigation and land locomotion, has been much insisted on by projectors of rotatory engines. To both these purposes it is, from its form, supposing it to possess no other disadvantage, most inapplicable. In a steam-vessel, it is first of all desirable to have the axis of the paddles as high as possible, and the weight of the engine as low as possible. Now if the engine be placed on an axis, which is the case in this application of the rotatory engine, one of two evils is incurred: either the axis of the wheels must be brought low, which impairs the action of the paddles, or the weight of the engines must be exalted so as to render the vessel top-heavy, unsteady, or, as it is technically called, "crank," and liable to be upset. By the ordinary engine, the axis is elevated to or above the deck, while the weight of the engine remains on the floor, at the bottom of the vessel. Again, to the application of the rotatory steam-engine to the purpose of terrestrial locomotion in propelling carriages on railways or other roads, there are insuperable objections. As the rotatory engine is placed immediately upon the axle of the propelling wheels, there can be no springs between it and the wheels, so that every jolt would derange the machinery. The weight of the engine placed on the axle would in turn reciprocate the evil by knocking the wheels to pieces. In the reciprocating engine these evils are prevented by the detachment of the engine from the axle, and the propagation of power through rods, wheels, or chains, to the propelling wheel or axis; and if any fault still remain in the principle of locomotive engines, it is the want of perfect detachment in the very respect which the introduction of the rotatory engine would render impossible.

In addition to all these obstacles which stand in the way of rotatory engines, it may be worth while to men-

tion another circumstance of a practical nature which gives great superiority to the common steam-engine; we mean the facilities which it presents, and which the rotatory engine does not possess, for the attachment of the appendages that are indispensable to the functions of a perfect steam-engine. The subordinate parts of an engine which belong equally to a rotatory and reciprocating steam-engine are, an air-pump, a feed-pump, and a well-pump. These merely require to be attached directly to the beam of the common engine, and they are worked without the intervention of auxiliary mechanism, because the motion of the pumps is reciprocating, and the action of the steam is also in the common engine reciprocating; while, on the other hand, in the case of the rotatory steam-engine, it would be necessary to convert the revolving movement, by a crank or other more complex mechanism, into the very reciprocating effect which it is intended to supersede.

All these considerations, of a most important and immediate practical bearing, clearly prove that although, in the most abstract and elementary theoretical view of the subject, there be an apparent equality of effect in the rotatory and the reciprocating steam-engines, yet there are practical objections of an insuperable nature inherent in the very constitution of rotating mechanism, that prevents the possibility of rendering it more perfect.

III. It is lastly our duty to show that the common reciprocating crank steam-engine, not only does not possess the disadvantages attributed to it, but that it possesses certain very peculiar properties which may not have been hitherto clearly understood and defined, but which nevertheless do adapt it in so admirable a manner to the nature of steam and of solid matter, and to the necessary imperfections of all human mechanism, as to have rendered it triumphant in universal practice over every competitor.

1. It was long imagined that the transmission of power through a *crank*, or *bend*, or *handle* in an axle, was attended in the steam-engine with great loss of effect. In the opinion of such men as Smeaton, the crank was never likely to be used as the means of obtaining rotatory motion from steam; while it is this very crank that is, in our day, used alone and universally over all other methods, although a great variety of other methods have been successively invented, and finally abandoned for the simple elementary crank. Yet it is not without some show of reason, that objections have been made against the practical working of the crank. We admit that the argument was rather a staggering one, but the difficulty has lately been wholly removed.

The staggering fact, to which we refer, was this: it is given as stated by Dr Penneck of Penzance, Cornwall, in describing a substitute proposed by him for the crank. "Some have considered a wheel as one-third more powerful than the crank, and others that no power is lost by the crank; but, confining myself to *practical results*, it appears from the report of the duty of steam-engines as done in Cornwall, and published by the Messrs Lean, that the performance of the crank-engines bears no proportion to those in which no crank is employed." He then proceeds to show the advantages of his own engine, in which a ratchet-wheel is moved by an arm, always acting at the extremity of a radius, by which means he hopes to save the loss of power occasioned by the crank. The fact related by Dr Penneck was perfectly accurate. It had happened that the crank steam-engines, working expansively in Cornwall, had never given out an adequate effect. That the fault did not lie in the crank, but in other parts of the arrangement, is now apparent: it consisted in the want of proper adjustments to admit of favourable action in using the steam expansively. Ar-

Steam-Engine.
Rotatory Engines.

The Crank considered.

Steam-
Engine.
Rotatory
Engines.

rangements for this purpose have, however, been at length accomplished, and crank-engines are now in Cornwall doing the same work as the average of those that have no crank. We have before us the printed reports of last year, stating the duty done by the crank-engines of Charleston and Wheal Kitty, constructed by Mr Sims. We have also before us indications of the *actual pressure of the steam on the cylinder*, as obtained by a very accurate indicator, applied in the course of the summer of 1837 by Mr Smith for Mr Fairbairn of Manchester, who visited the mines for that purpose, and has been kind enough to favour us with a copy of his diagrams and observations. We have thus the means of comparing the power actually exerted on the piston with the work done, and find the result of the comparison to be, that *the work done is within ten per cent of being perfectly equal to the power employed*. Here, then we arrive at this conclusion, that the utmost conceivable reach of improvement in the mechanism of the steam-engine, if it even attained to perfection, would not save more than a few per cents. That the crank engine is, therefore, as at present used, as near in practice to the perfection of mechanism as any thing we can hope to obtain, is, we think, satisfactorily explained.

2. The crank, as a means of converting the reciprocation of the piston of a steam-engine into continuous revolving movement, possesses certain singular and beautiful properties which distinguish it from every other means of producing that conversion, and which appear to be so perfectly adapted to the nature of steam and the constitution of solid matter, that we are indebted to it materially, though indirectly, for the very great advantages which we derive from the modern steam-engine as a source of mechanical power. Let us examine into the causes of this well-established practical superiority of the crank to all other modes of producing revolving motion. Let it be observed, that in the reciprocating piston, from which the crank derives its motion, the following things take place: the piston is to be put in motion in one direction, then stopped, then put in motion in the opposite direction, stopped again, and then its motion resumed in the first direction. We shall see how admirably the crank adapts itself to these changes; so that, while the piston with which it is rigidly connected takes every velocity between its maximum velocity and perfect rest, the crank goes forward with a motion perfectly regular and perfectly unimpeded. The necessity of this gradual change from motion to rest, and a reverse direction of motion, is obvious. Matter in motion acquires momentum and cannot be stopped, but its impetus must be equally and gradually removed, otherwise these moving parts are subjected to concussion as if by the stroke of a hammer, and must either suffer injury or produce it; for, when in motion, matter requires a force to stop it equal to the force which gave it that motion. And, on the other hand, when brought to rest, matter cannot instantly be set in motion in the opposite direction without a stroke and concussion equally violent. To work smoothly, durably, profitably, and uniformly, matter must be put in motion by gentle gradations, beginning with a very gentle velocity, and gradually increasing in velocity like a body set in motion down an inclined plane, where, if it move one foot in the first second, it moves three in the next, five in the next, seven in the next, and so on: and in like manner in coming to rest, it must do so in the same gradual way in which an arrow shot from a bow vertically into the air loses its motion; for in the end of its course it moves seven feet in the first quarter of the last second of time, five feet in the next quarter of a second, three feet in the next, and only one foot in the last, and then subsides into rest at the instant

before it again recommences motion downwards, which it does in a manner perfectly similar. It is required, therefore, that while the motion which the steam gives off by the crank be uniform and continuous, the parts of the engine itself shall be allowed time to be alternately brought into a state of rest, without shock, concussion, or jolt, and equally, gradually, and gently be again urged to their greatest velocity in the opposite direction. All this the crank effects with the most exquisite nicety of adjustment; it stops the piston when in motion as gently and softly as if a cushion of eider were placed to receive it; and after having brought it to rest again begins and accelerates its motion, as gradually and gently, to the highest velocity in the opposite direction. An adjustment so perfect is only possible in such a relation as that which subsists between the circle of the crank and the axis of the piston. Now if we compare this mode of action with any of the substitutes for the crank, by which it has been proposed to gain uniformity of power, we shall find that in these it would be required that the transitions from rest to motion and from motion to rest should be instantaneous; and hence such arrangements, being soon disordered, have been abandoned. It will also be found that in rotatory engines it is necessary that the transitions and changes of arrangement, where these exist, are necessarily instantaneous, or if not, that steam is lost, or that the boasted uniformity of power is sacrificed.

3. The next property of the crank, as an elementary machine for the conversion of motion, is its remarkable power of reducing errors of construction, arrangement, and execution. It is one of the highest recommendations of a piece of mechanism that any trivial errors committed in its construction shall not materially injure its efficiency; and that any slight derangement in its adjustment shall not be attended with immediate deterioration or aggravated injury; but that, on the other hand, the efficiency of the machine shall be consistent with such degrees of correctness in workmanship, and accuracy in adjustment, and care in making use of it, as are consistent with the ordinary amount of intelligence and attention of ordinary workmen; and that the progress of derangement and necessary tear and wear shall be so gradual as to give timely warning of danger, and admit of ready repair and re-adjustment. The crank is precisely such a piece of mechanism. Errors in adjustment or construction of valves and other vital mechanism, are diminished in effect by the crank one hundred-fold; the changes of the valves, the essential part of the mechanism, take place only at the top and bottom of the stroke. Now at these instants the crank is on the "line of the centres," as it is technically called; and it is just in this position that a minimum of force is made to act on the crank, so that if the valves do not open with perfect precision, but either a little too soon, or a little too late, then will such error at that part of the circuit be of comparatively trifling consequence, because then the motion of the piston is so slight, that through an arc of twenty degrees of the crank it does not describe the hundredth part of that space; and the effect of any error committed within that range, will not affect the result in the crank by one hundredth part of its full amount.

In like manner, errors in management and errors arising from wearing, are reduced a hundred-fold in effect by transmission through the crank. It has frequently been to us matter of astonishment, to see at the mouths of coal-pits, mines, and quarries, mere remnants of engines, frail rusty old fragments of iron and wood, so loose as scarcely to stand upright upon their bases, to see these superannuated drudges still performing heavy work to a very large percentage of their full power.

Steam-
Engine.
Rotatory
Engines.

Steam-Engine.
Rotatory Engines.

4. To these circumstances we may add, that it is to the possession of these properties that we may attribute the fact, that reciprocating engines are constructed of enormous weight in their moving parts, and of ponderous dimensions, without being thereby sensibly deteriorated in working. The crank acquires a slow motion at the commencement of the stroke, and an accelerated motion is thereby acquired in a manner equally gradual by all parts of the machine; and in like manner, at the termination of the stroke, it brings them to rest again in a gradation so gentle and uniformly retarded, as again to receive from them much of the impetus which it had formerly communicated. The impetus, therefore, given to the reciprocating parts is only *lent*, not *lost*.

General Conclusions.

We have thus endeavoured to expose the nature of the fallacy under which they labour who imagine that the present steam-engine, as derived from Watt, is a machine which destroys or absorbs a large portion of the power it is designed to transmit, and who look to the rotatory engine as a means of increasing the amount of the power given out in useful effect. That the rotatory engines which appear day after day are not new, we show from the fact, that the five great classes which comprehend them all have already been invented and re-invented by upwards of a hundred individuals. That their inventions have been unsuccessful, is manifest from the non-existence of their machines in the daily use of ordinary manufactures. That the failures of these contrivances did not arise from defects accidental to the peculiar arrangements and contrivances of the engine, is rendered probable by the great variety of forms in which they have been re-invented, tried, and abandoned. That they have not failed from deficiencies in the workmanship and practical details, is rendered still more probable by the circumstance of finding among the names of inventors those of the most eminent practical engineers. We have next shown, that in theory, the crank of the steam-engine in common use cannot, as has been supposed, be attended with a loss of power, as such loss would oppose the established doctrine of virtual velocities. It is also shown, from very simple and elementary considerations, that what appears to be lost in force is resumed in velocity; that in proportion as the mean force on the piston is greater than the mean force on the crank, in that proportion is the space described by the latter greater than the space described by the former; that the dynamical effect produced in a given time, is exactly in the proportion of the steam expended in that given time. And thus have we arrived at the conclusion, that the common reciprocating crank steam-engine has not the faults attributed to it in theory, and which the rotatory engines have been designed to remedy. We have next taken the practical view of the subject. In simplicity of parts, the rotatory engine has no advantage over the reciprocating piston; in difficulty of construction, the rotatory piston far exceeds the reciprocating engine: it is more expensive at the outset—it has more friction—it is more bulky and less compact—it is inferior in precision and uniformity of action to the crank-engine—and there is a radical fault inherent in the very nature of rotatory mechanism, from which it follows that the rotatory engine can never be rendered either an economical or a durable machine. We have further shown, that even if the rotatory engine could be made economical and durable, its very nature renders it unsuited to the great purposes of steam navigation and inland locomotion; objects to which it has been considered peculiarly applicable. We deemed it an appropriate and instructive conclusion to our enquiry, to examine into

the action of the crank, for the purpose of discovering what those remarkable qualities are which have given to the crank of the common steam-engine its unrivalled superiority as an element for the production of circular motion, and a degree of perfection unattainable by any other mechanism. We have seen that well constructed crank steam-engines are daily performing duty which is within ten per cent of the theoretical maximum of possible effect—of absolute perfection; that this practical perfection arises from the simplicity of the crank, from its wonderful adaptation to the nature and laws of matter, and of circular motion in connexion with rectilineal motion—from its reduction of errors either in construction, adjustment, or management, so as to work well without the absolute necessity of greater intelligence, expertness, and precision than belong to ordinary workmen—and from the compensating nature of the arrangement of its structure, by which it is accommodated in a remarkable degree to the necessary imperfections of all human mechanism.

Steam-Engine.

ON STEAM-ENGINE BOILERS.

The construction of a boiler must appear so simple an arrangement of materials, as to require very little ingenuity or contrivance; a large enough boiler placed upon a large enough fire being sufficient to generate any requisite supply of steam. Simple, however, as such an arrangement may seem, the best construction of boiler is a subject upon which very widely different and even opposite opinions are entertained by men of the greatest science and experience. There is perhaps no branch of practical art in which so much remains to be determined and improved, and scarcely any which science has done so little to advance. To follow servilely what has, in a given instance, been “found to answer,” is the rule of the most sagacious mechanics, and the doctrine of the wisest authors. Those who have attempted to invent have commonly erred; those who have generalized have invariably been rash and unsuccessful, and their erroneous theories have led astray their followers, when they happen to have any.

The art of constructing steam-boilers is, we have said, in its infancy; but it is likely, we think, to make rapid progress. The construction of the boiler of the locomotive-engine, which every day performs what at a former period we should have termed impossibilities, exhibited a strikingly anomalous phenomenon, by which the attention of all men who thought upon such subjects was suddenly arrested: this little barrel of water generates as much steam in an hour, as would formerly have been raised from a boiler and fire occupying a considerable house. The frequent explosion of boilers, both here and in America, has also directed attention to the efficient construction of boilers. The patient experimental enquiry that has since been set on foot, must lay open the whole of the important parts of the question so thoroughly, and bring out the facts with such clearness and precision, as to lead, by safe and rapid induction, to the general principles by which we may be able to predict the result of every supposed case, and deduce safe rules for the guidance of practical men in all circumstances. The investigation of the whole subject of steam-boilers, recently undertaken in America by the Franklin Institute, has already done much to settle many points of dispute. The publication of the reports of the American and English Governments on the explosions of steam-boilers, has elicited many valuable contributions

Steam-
Engine
Boilers.

to the stock of knowledge; the useful practical treatise of Mr Armstrong has given us an instructive view of the state of practice in the busy district of Lancashire; the treatises of Mr Wood and M. de Pambour on Railway Locomotives; and the papers, in the Transactions of the Institution of Civil Engineers, on the statistics of Boilers and Combustion, have supplied and discussed a large collection of important facts, that will materially assist the future investigation of the best construction of steam-boilers.

During the first period of the history of the steam-engine, the danger of bursting the boiler, and the difficulty of making it strong enough to resist the internal force acting towards explosion, and also of making the joints tight against the leakage of highly elastic steam, formed the chief obstacles to the introduction of steam as a mechanical mover.

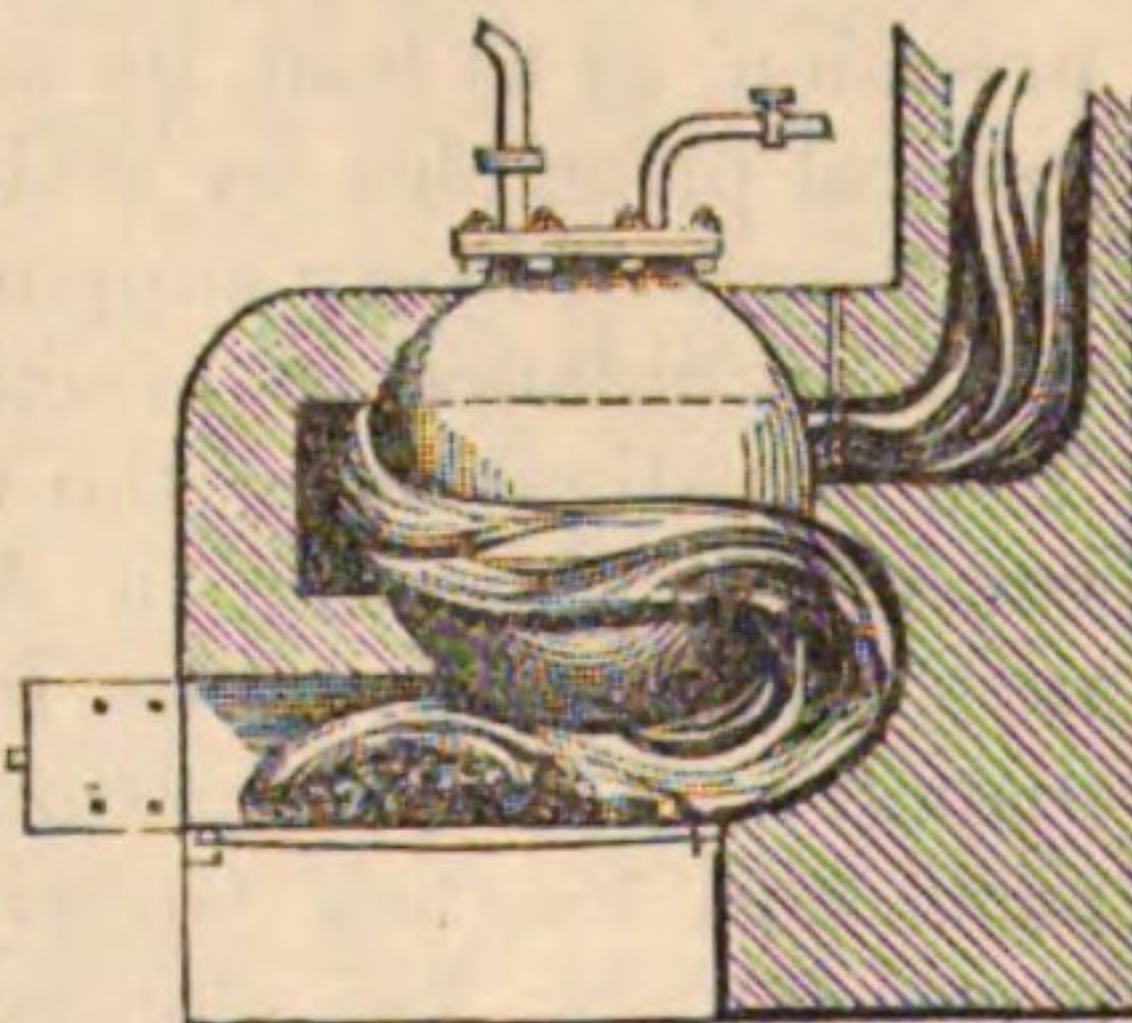
The first important point in preparing a steam-boiler is to secure strength, without unnecessary expense of materials. If we take the simplest form of vessel: suppose a simple rectangular water-tank—suppose the vessel on a small scale, made of sheet-iron, and soldered at the edges so as to form an air-tight box; then, by simply blowing into it, we shall manifest its weakness; for the sides will first of all bulge out, and, if the materials yield and allow the vessel to change its shape, it will at last swell into a globular form, with angular knobs upon it at the corners, from which pyramidal extremities, the globular parts, will finally be torn away with an explosion, which will, in all probability, take place long before the vessel has attained the shape mentioned above.

The Spherical Boiler.

The globular or spherical shape was very early adopted, as one of greatest capacity, as a shape in which, the pressure at every point being equal, there remained no force tending to produce flexure, or destroy the equilibrium of strength and strain at any point. A fire was then lighted below the boiler, and the steam confined until the heat had raised it to the temperature required for the given pressure. This form was accordingly adopted by Hero, Savary, and others, as may be seen in the representations of their boilers, which we have given in the historical portion of the article STEAM-ENGINE.

It was soon found that a spherical boiler, being set upon an open fire, required an enormous consumption of fuel to raise a small quantity of steam, the heat being copiously radiated not alone to the water in the boiler, but also in very great quantity to the surrounding objects, besides being rapidly carried off by the air. To surround the spherical boiler with non-conducting substances, and to keep the flame throughout its whole extent in contact with the surface of the boiler, so as to prevent radiation to surrounding objects, and also to diminish the size of the fire by making it wind round the boiler, were the first steps towards improvement; and we accordingly find in the work of Dr Desaguliers the subsequent form of a boiler. Fig. 198 is a front view of the boiler set in a building of brick, a substance which is good as a non-conductor of heat, and calculated to withstand the destructive action of fire. A deep *ash-pit* lies immediately under the fire, which rests on a number of parallel iron bars, placed so close to each other as to prevent the fuel from falling through, and at the same time to admit between them the air requisite for combustion;

Fig. 198.



and the door of the furnace being kept closed at all times, except when fuel is to be added to the fire, the whole of the matter of the fuel is in this way supplied with air, which passes up through the interstices of the bars. The flame, after having passed along the bottom of the boiler, winds in a corkscrew form around its sides, in contact with the surface of the boiler, in a spiral channel formed by the bricks, and called a *flue*, by which the smoke and hot air are at last conveyed into a chimney. A *damper*, as it is called, is formed by a small plate of iron, admitted through a slit into the opening where the flue joins the chimney; so that, by pushing this plate into the opening, the passage of the smoke out into the chimney, and consequently of the fresh air into the fire, may be obstructed, the combustion of the fuel retarded, and the too rapid generation of steam prevented. In this simple way, the attendant is enabled, by merely pushing in or drawing out the damper, to regulate with great precision the generation of the steam. The pipe which conducts the steam to its ultimate destination, is called the *steam-pipe*; and there is another pipe necessary to the continued action of the boiler, called a *feed-pipe*, through which water may be made to enter the boiler, as it is evident that otherwise the water, being continually boiling off in the shape of steam, would soon leave the boiler empty; so that a constant supply of an inch of water for every foot of steam, or six gallons of water for every horse power, is required to enter the boiler through the feed-pipe.

The form of boiler next in simplicity to the spherical boiler is the cylindrical. From the facility with which a cylinder is made, it was introduced at a very early period. It stood upright, as in fig. 199, the fire being

Steam-
Engine
Boilers.

Fig. 199.

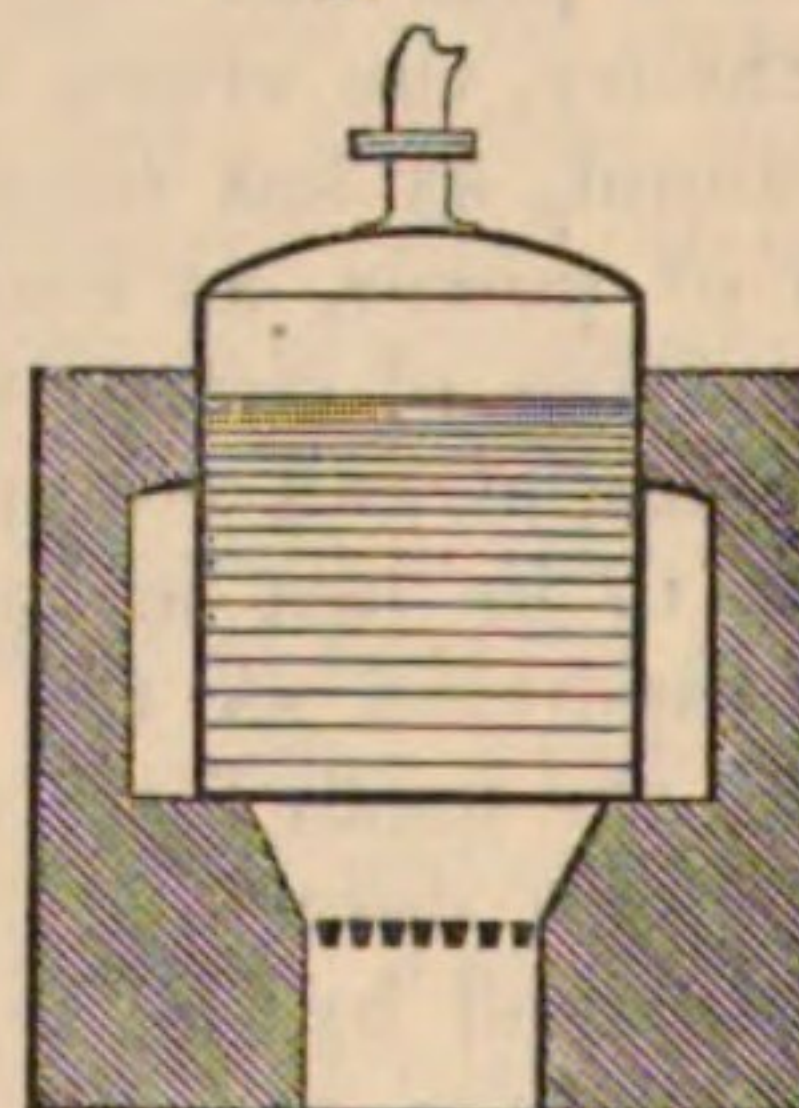
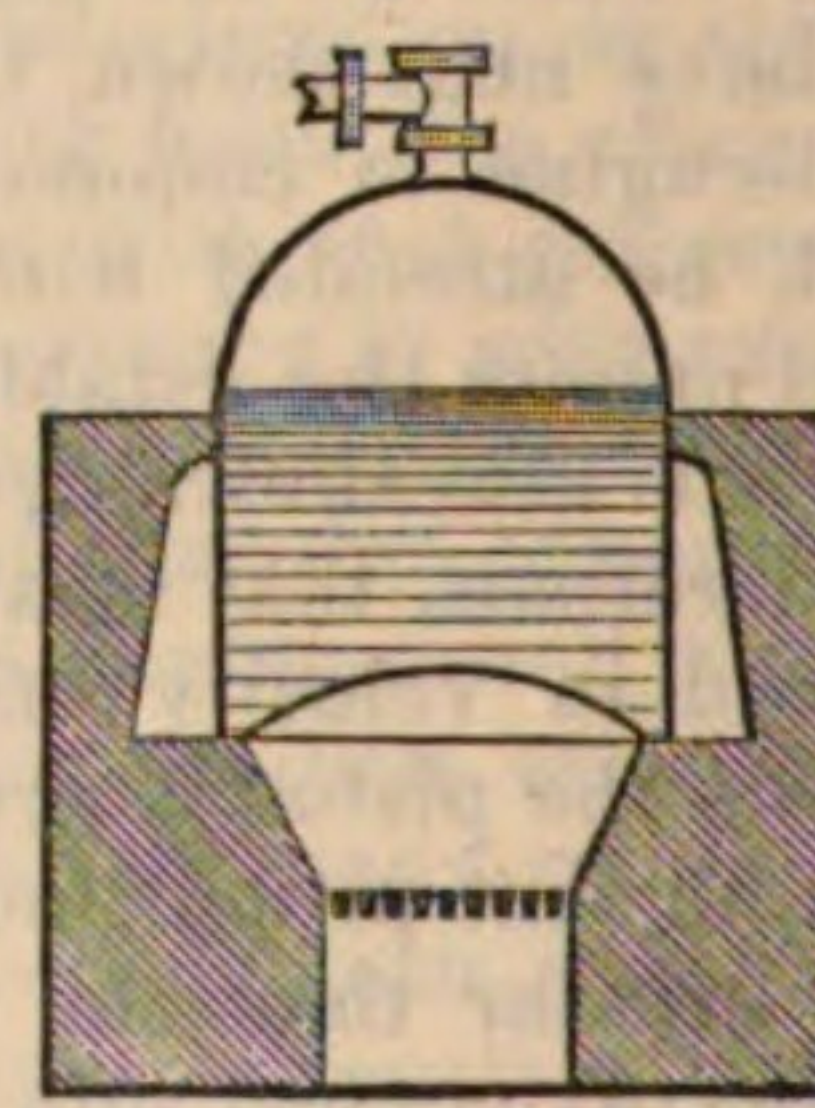


Fig. 200.



The Upright Cylindrical Boiler, and the Cylindrical Spherical Boiler.

placed at the bottom, and the flue winding round that part of the sides covered with water. This form of boiler was found, however, to have the disadvantage of weakness in the bottom part.

For the prevention of these two evils, the cylindrical form of boiler was very soon modified and improved by two opposite expedients, one applied at the top and the other at the bottom of the cylinder. The top being made hemispherical, possessed all the advantages of a spherical boiler; and the bottom being arched upwards, so as to present a large concave dome to the impact of the flame, this dome being sustained by the cylindrical belt round its spring, a very strong and extensive surface was obtained, as in Fig. 200.

In this cylindro-spherical boiler, it was found that the action of the flame on the upright round sides produced a very slight effect in raising heat. It was therefore desirable that the flame should be brought somewhat under the sides, by inclining them a little outwards. The boiler then assumed a form which has since become very common, and from its shape, has not inaptly been named the haycock boiler, fig. 201.

Steam-Engine Boilers.

The Haycock Boiler and its Modifications.

Fig. 201.

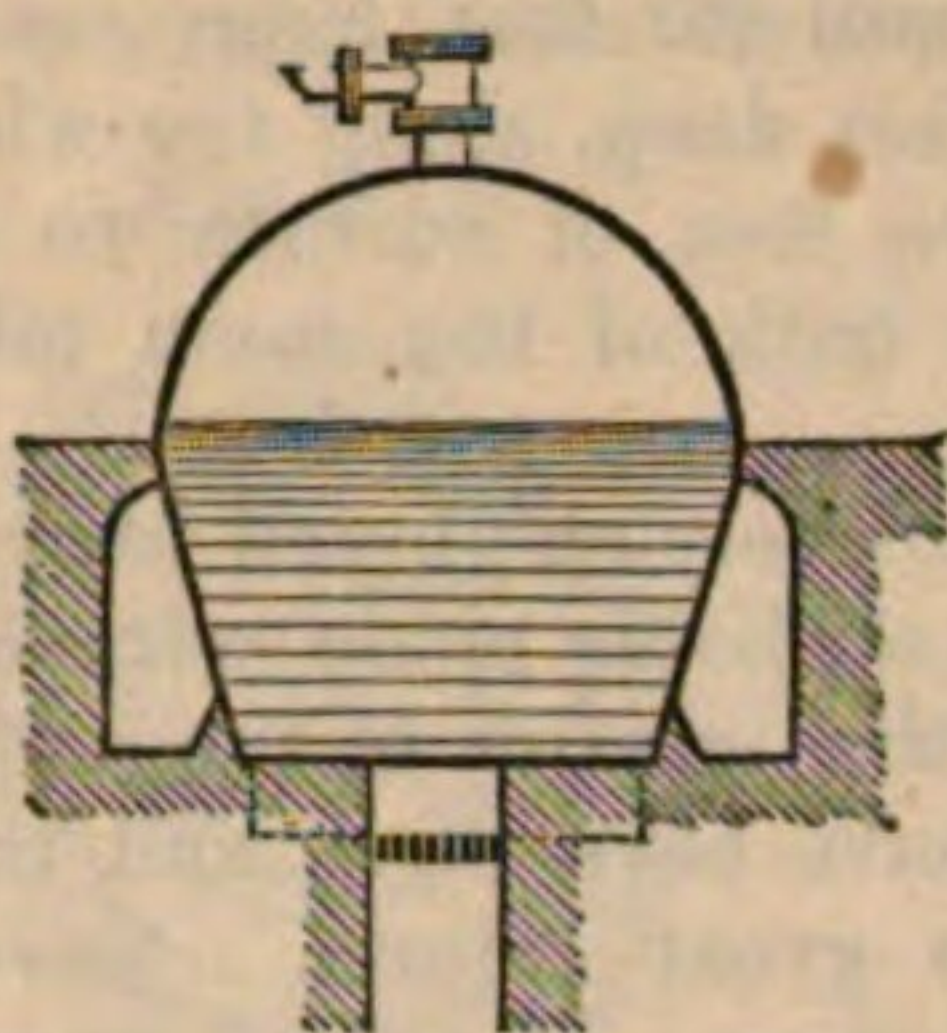
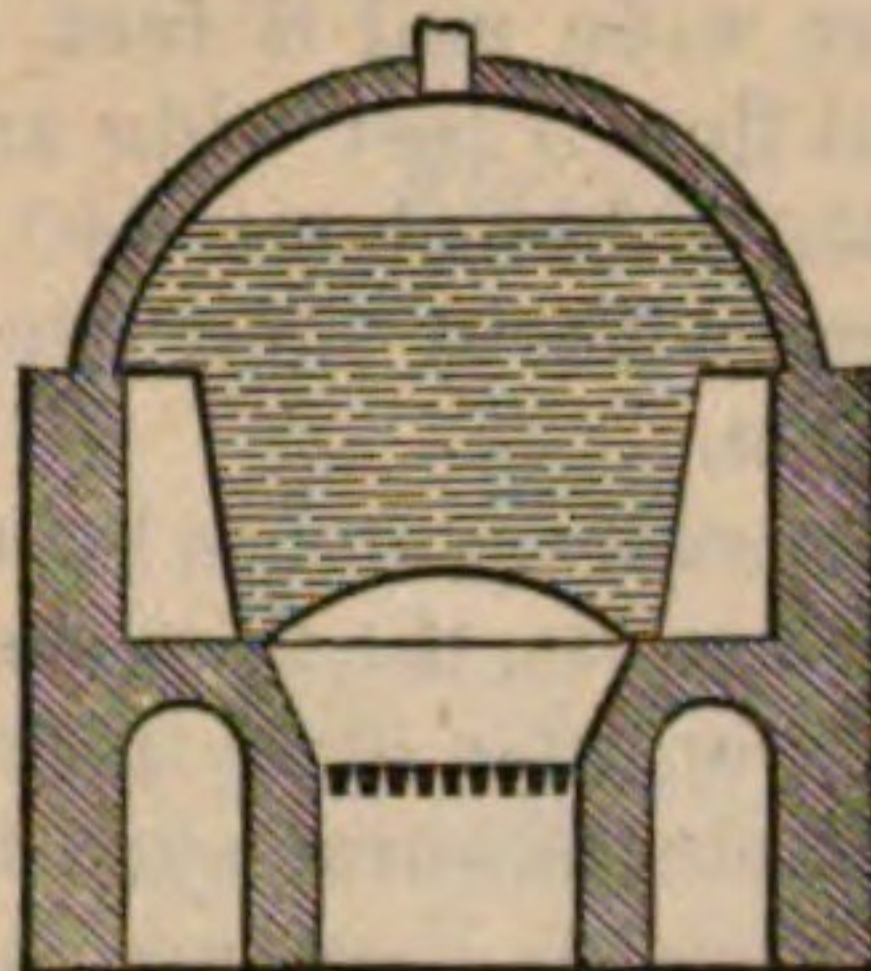


Fig. 202.



The same effect was next obtained in many of the boilers of Newcomen, in the way represented in fig. 202, so that the flame in the flues impinged upon a surface directly over them; the flues in this case forming a recess in the sides of the boiler, instead of being built around it by the brickwork alone. In process of time, boilers of much larger size came to be required, and the spherical shape was found cumbrous and too capacious, that is to say, contained an enormous mass of water, which it required much time and fuel to heat to the boiling point before any steam could be raised. The diameter, also, of the boiler was so great when much steam was required, that the enormous dome became weakened. To make a stronger boiler, and one which should, at the same time, cover a large fire, the *waggon boiler* was introduced by Mr Watt; an oblong boiler, of whose form no better definition can be given than the descriptive epithet which forms its name. It closely resembles those long, heavily laden, four-wheeled waggon, which a team of six or eight horses may occasionally be seen dragging along with difficulty.

The Waggon Boiler.

The waggon boiler is made of considerable length, and its transverse section, fig. 203, resembles that of the old circular boiler.

Fig. 203.

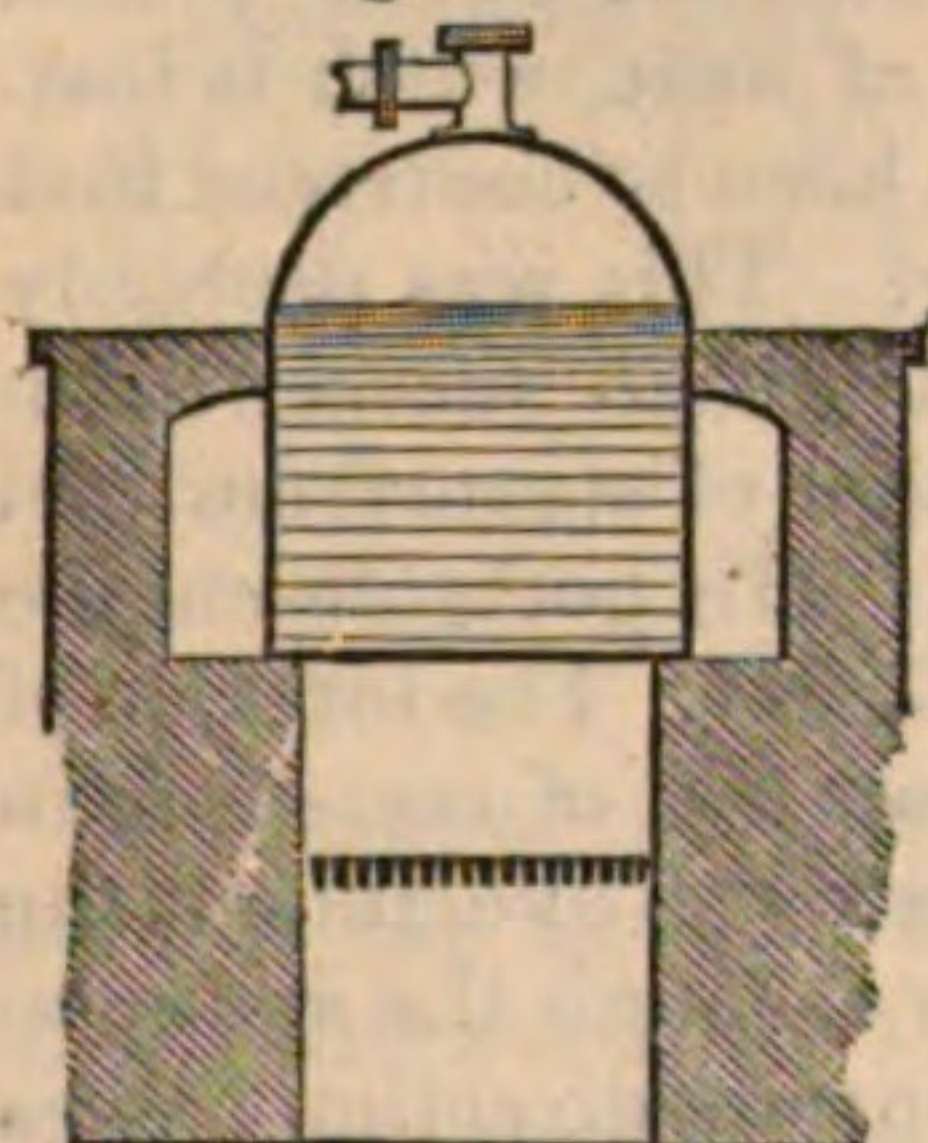


Fig. 204.

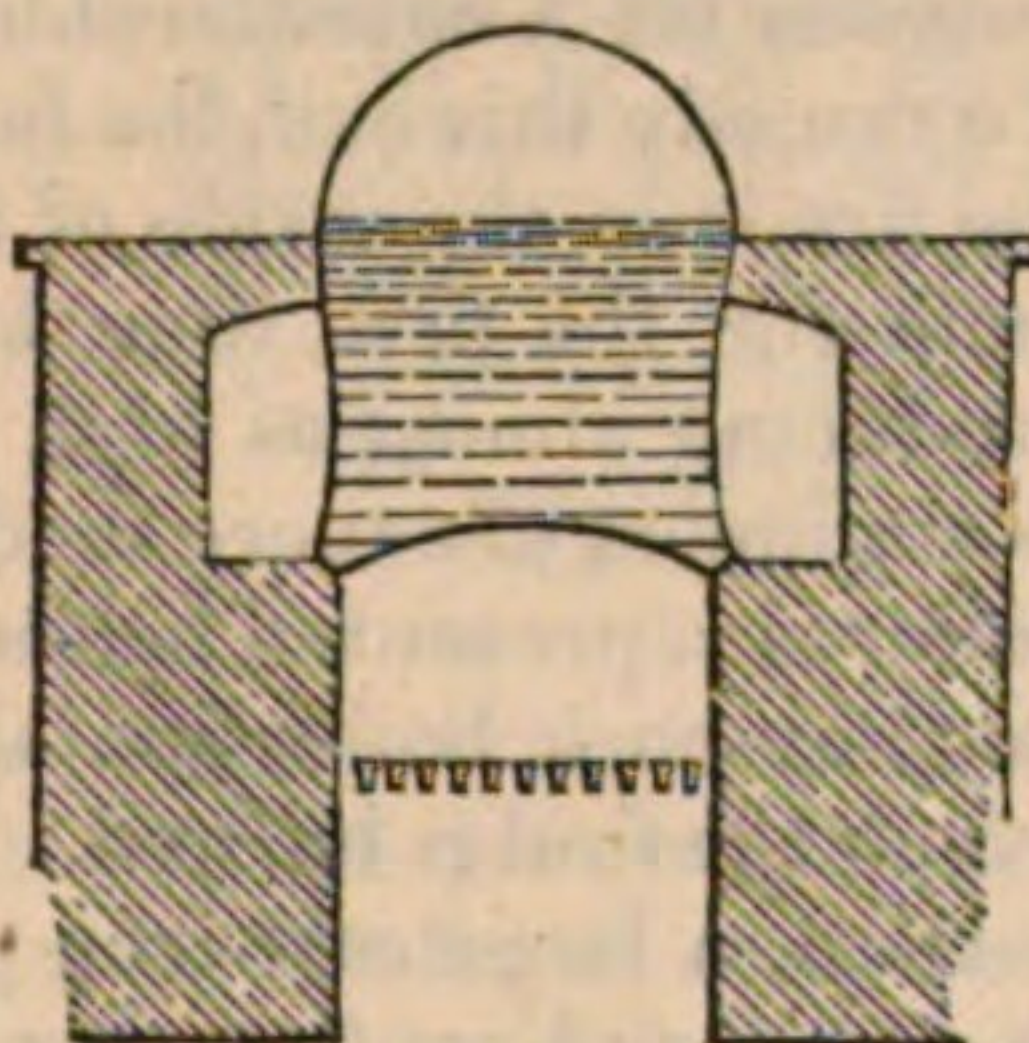
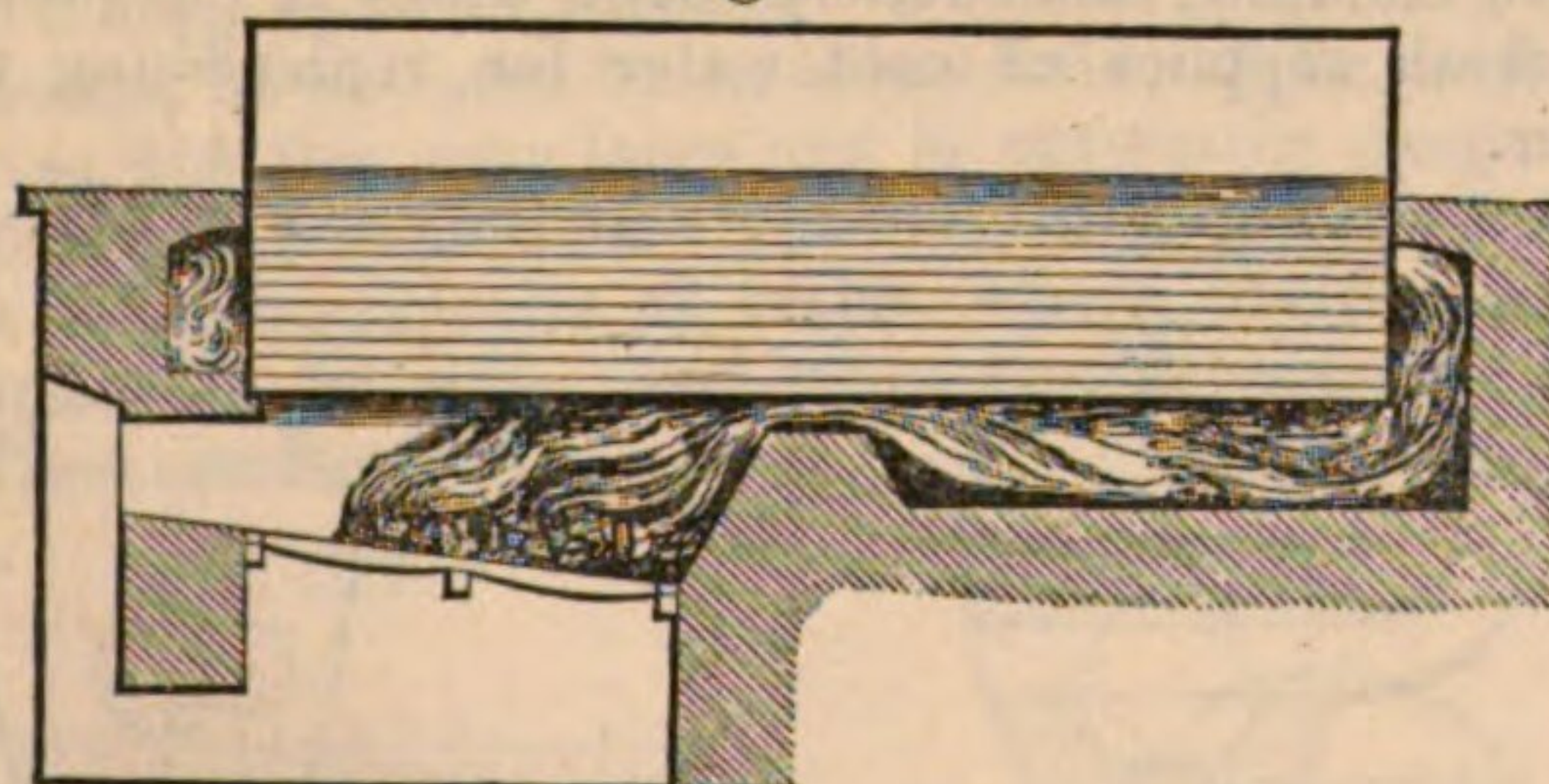


Fig. 205.



In this form the boiler was long made by Messrs Watt and Bolton. It was afterwards improved by hollowing inwards the sides, for the purpose of bringing them more immediately over the flame. Of this form of the waggon boiler, which is universally used at the present day, fig. 204 exhibits a transverse, and fig. 205 a longitudinal section. These forms of boiler, although very convenient, are weak: they are very different from the spherical or cylindro-spherical boilers in strength and

VOL. XX.

safety. The metal of which they consist is not in the form that will resist, to the utmost of its tensile force, a change of shape; but, on the contrary, a very small pressure has been found sufficient to bulge these boilers downward towards the fire, and outwards at the sides.

Steam-Engine Boilers.

From this circumstance it has been found necessary to place in them strong iron stays, for the purpose of connecting a given part of the surface of the boiler having a tendency to bulge out in one direction, with a similar portion of surface, having a tendency to bulge out in the opposite direction; so that this tie-bar being stretched in opposite ways, is made to resist, by its tensile force, the outward or bursting pressure. These stays are essential to strength and security in boilers having large surfaces, concave outwardly, or perfectly flat. Their application to the forms of boilers which we have just described, is seen in figs. 206, 207, and 208.

Means used for Strengthening Boilers.

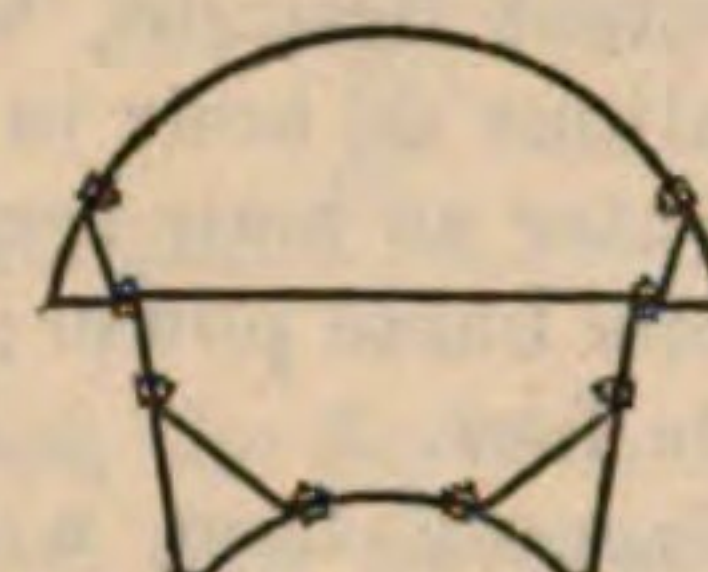
Fig. 206.



Fig. 207.



Fig. 208.



To avoid the use of stays, and to secure great strength without any other metal than the shell of the boiler itself, is the object of that construction of cylindric boiler now much in use, especially where considerable pressure is used. It is certainly one of the cheapest, safest, and best boilers. A cylinder, figs. 209 and 210, perhaps thirty feet in length and four feet in diameter, with two hemispherical ends, is laid with its axis nearly horizontal; and below it, at one end, is placed the fire, enclosed by brick, as usual. The flame traverses the bottom of the boiler, beating directly upon its under horizontal surface till it reaches the end farthest from the fire. The flame and hot air then return along the one side of the cylinder, being confined in a brick flue, and, passing along in front of the end which is over the fire, traverses the other side towards the chimney, which it enters after having thus traversed the length of the boiler three times, and applied its heat successively to every point of the cylinder which is covered with water. This is a boiler that requires no stays, and is valuable where room is not important. It contains much water, requires much heat to raise its temperature after being cooled at night, and is very bulky.

The Horizontal Cylindrical Boiler.

Fig. 209.

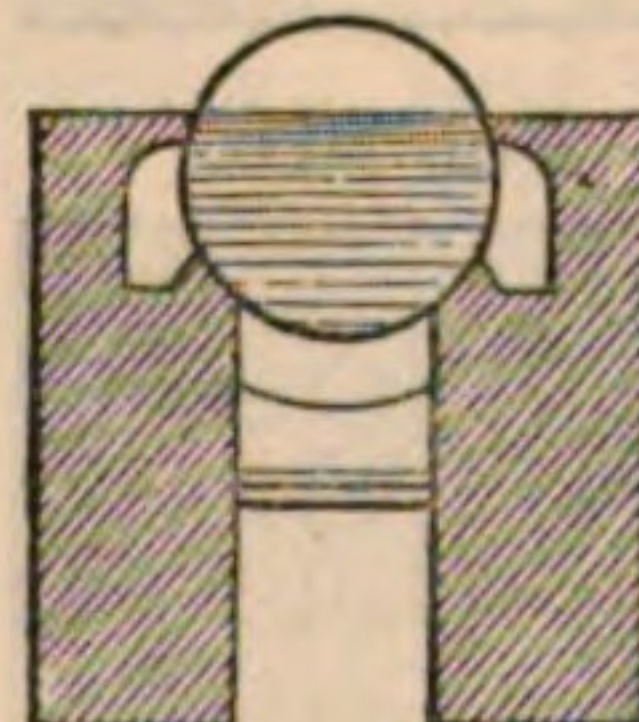
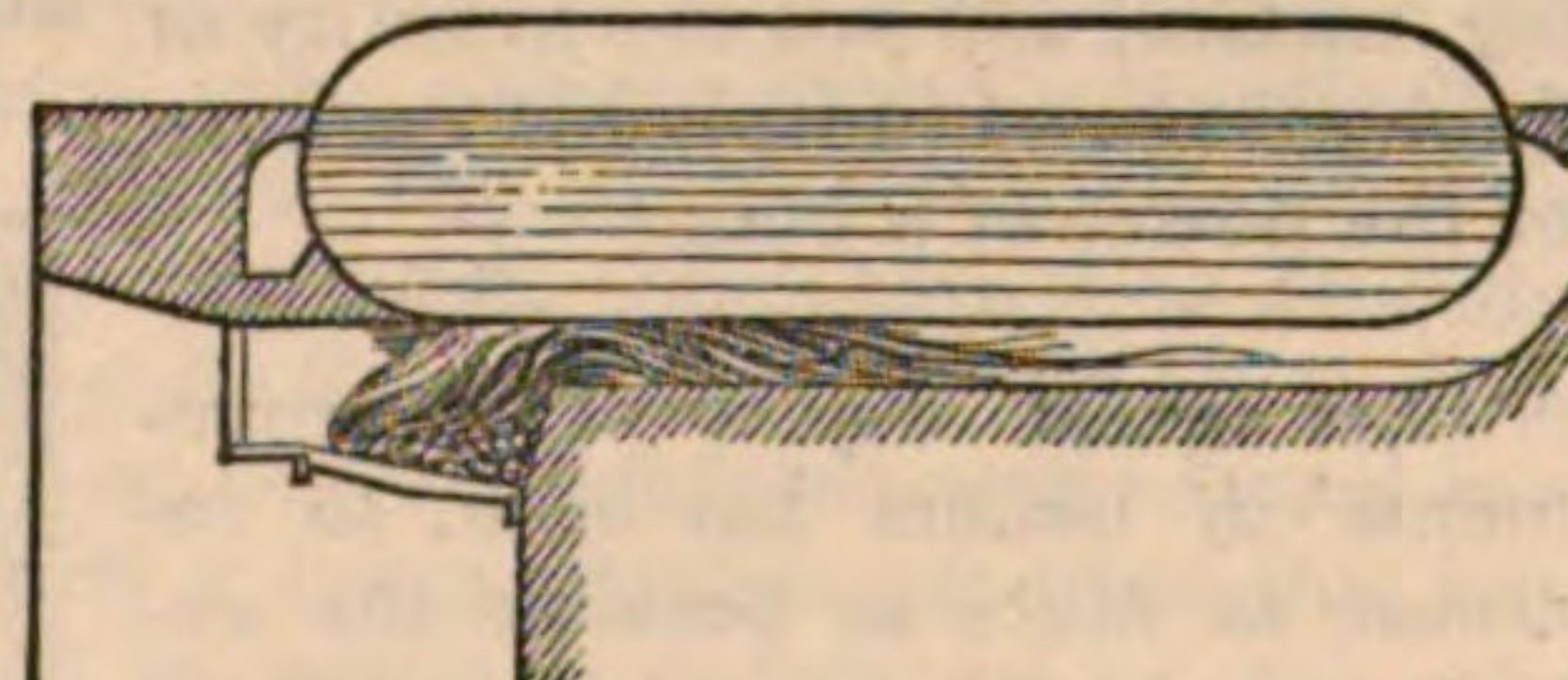


Fig. 210.



The Americans have adopted this boiler to a great extent. It was introduced among them by the ingenious Evans. It is generally of a smaller diameter than three feet, and has flat cast-iron ends of great thickness, which they call heads.

These boilers, the spherical, cylindrical, and waggon shaped, may properly be denominated the simple boilers. But some hundreds of kinds of boilers have been invented for different purposes; almost all of them designed to save either bulk, weight, or fuel. Some of these have been much more successful than others; and it

Steam-
Engine
Boilers.

is necessary to examine upon what principles any improvements attempted in boilers should proceed. In steam navigation, diminished bulk, weight, and consumption of fuel, are all objects of the first importance, as also in locomotive engines on land.

To make a little boiler generate a great deal of steam in a very short time, is a very difficult matter. Let any one take a common open caldron, or boiler such as is used to boil a few gallons of water; suppose the vessel to hold 84 gallons of water, to be set on a fire so that 9 or 10 feet of its bottom surface are exposed to the fire; then he will find that he cannot turn more than about 6 or 7 gallons of water an hour into steam. By blowing the fire violently, this quantity may be exceeded, but with a great waste of coal: and it will require a very good chimney, with an excellent draught, to produce even 6 gallons an hour in steam, which is about the quantity of water an hour required to furnish steam for an engine of one horse power; 6 gallons an hour being nearly one cubic foot.

Suppose, then, a greater quantity of steam is to be produced; how is that to be obtained? The answer is this: only by a larger boiler and a larger fire, acting on a larger surface. This general statement must be understood in the following way.

A larger boiler, calculated to generate more steam, does not exactly mean one which holds more water. It is found that the power of the boiler depends primarily upon the extent of its exposure to the action of the fire, or, as it is generally designated, the extent of heating surface. It appears that the heat cannot penetrate through the material of the boiler with more than a certain rapidity, and that the water evaporated over each square foot by the heat passing through, is not more than about $\frac{3}{4}$ ths of a gallon in an hour; and so it requires some 9 or 10 such feet of heating surface to boil off 6 gallons, or a cubic foot of water, capable of producing one horse power in the steam-engine. Now, for every such foot of heating surface there will be a corresponding generation of steam; and a boiler having 100 square feet of surface exposed to the fire will be capable of evaporating 100 times $\frac{3}{4}$ ths of a gallon of water an hour, being 60 gallons, and about 10 horse power. The extent of heating surface, and not the quantity of fluid contained in it, is the measure of the power of a boiler.

Boilers
with Inter-
nal Flues.

One great object of improvements in boilers has been, to increase as much as possible the extent of heating surface without increasing its general dimensions. One very efficient mode of doing this, is by the adoption of internal flues. Thus Bolton and Watt have inserted a flue in the middle of the large waggon boiler, in the manner shown in figs. 212 and 213; so that, after the flame has passed along the bottom of the boiler to the further end, it returns along the flue in the middle of the water to the front, and then makes an entire circuit of the outside of the

Fig. 211.



Fig. 212.

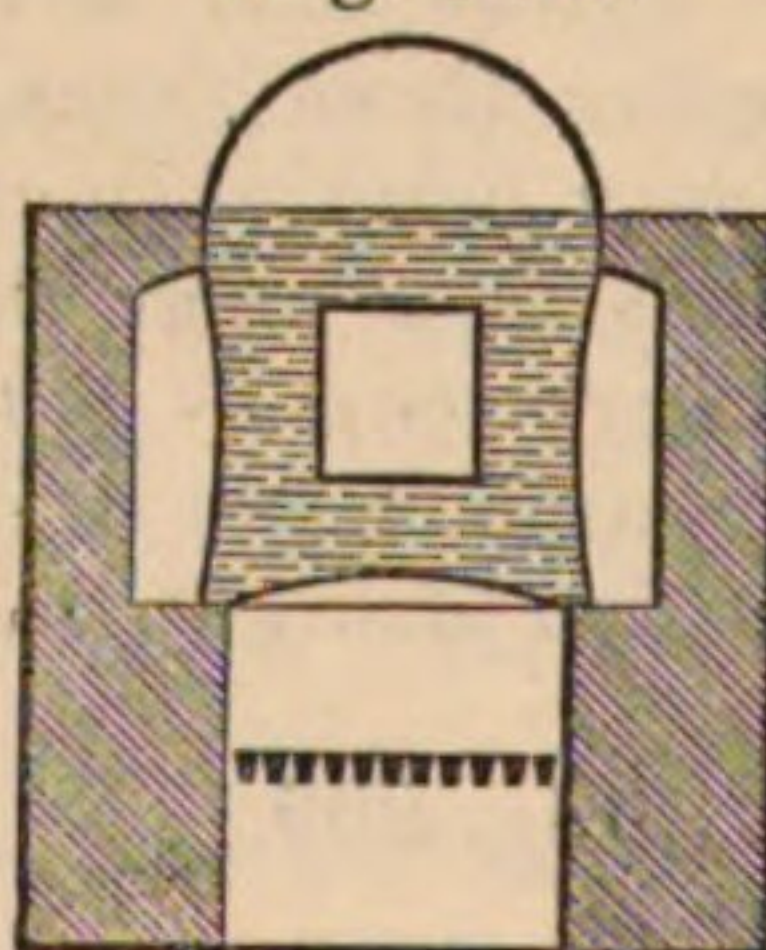


Fig. 213.



boiler before entering the chimney. Thus, in a boiler 6 feet wide and 8 feet high and 20 feet long, an internal flue 3 feet wide and 3 feet deep, along the whole length, adds about 240 square feet of surface to the boiler, without increasing the bulk of the room taken up by it.

The same plan has been extensively employed in cylindrical boilers, the flame and hot air being made to traverse a hollow tube or cylinder in the interior of the boiler: sometimes several such flues have been used, and these multiflued boilers are now in great repute. Several modifications are given in the figures. The small internal pipes or cylindric flues, surrounded with water, traverse

Steam-
Engine
Boilers.

Boilers
with Inter-
nal Flues.

Fig. 214.

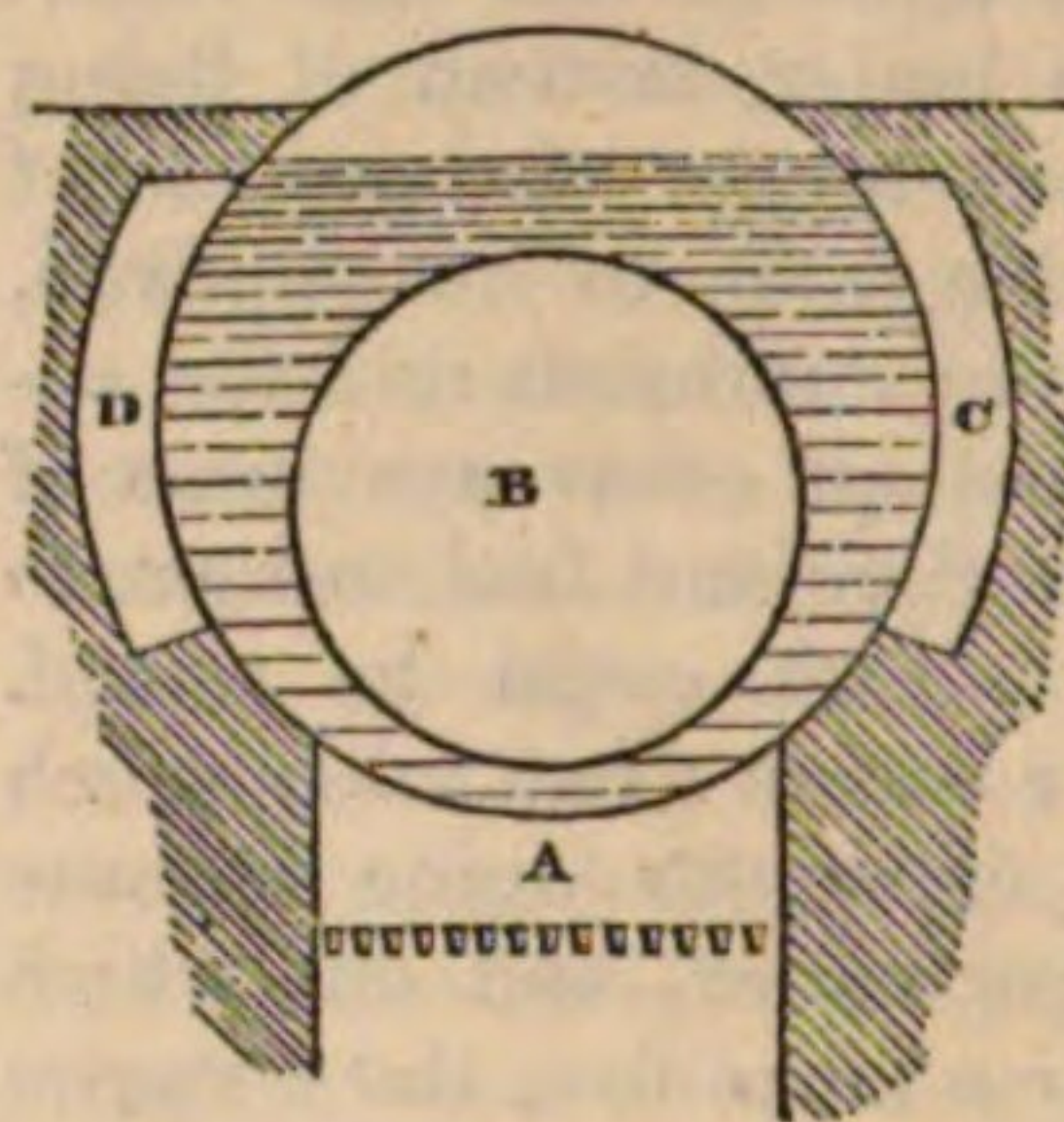
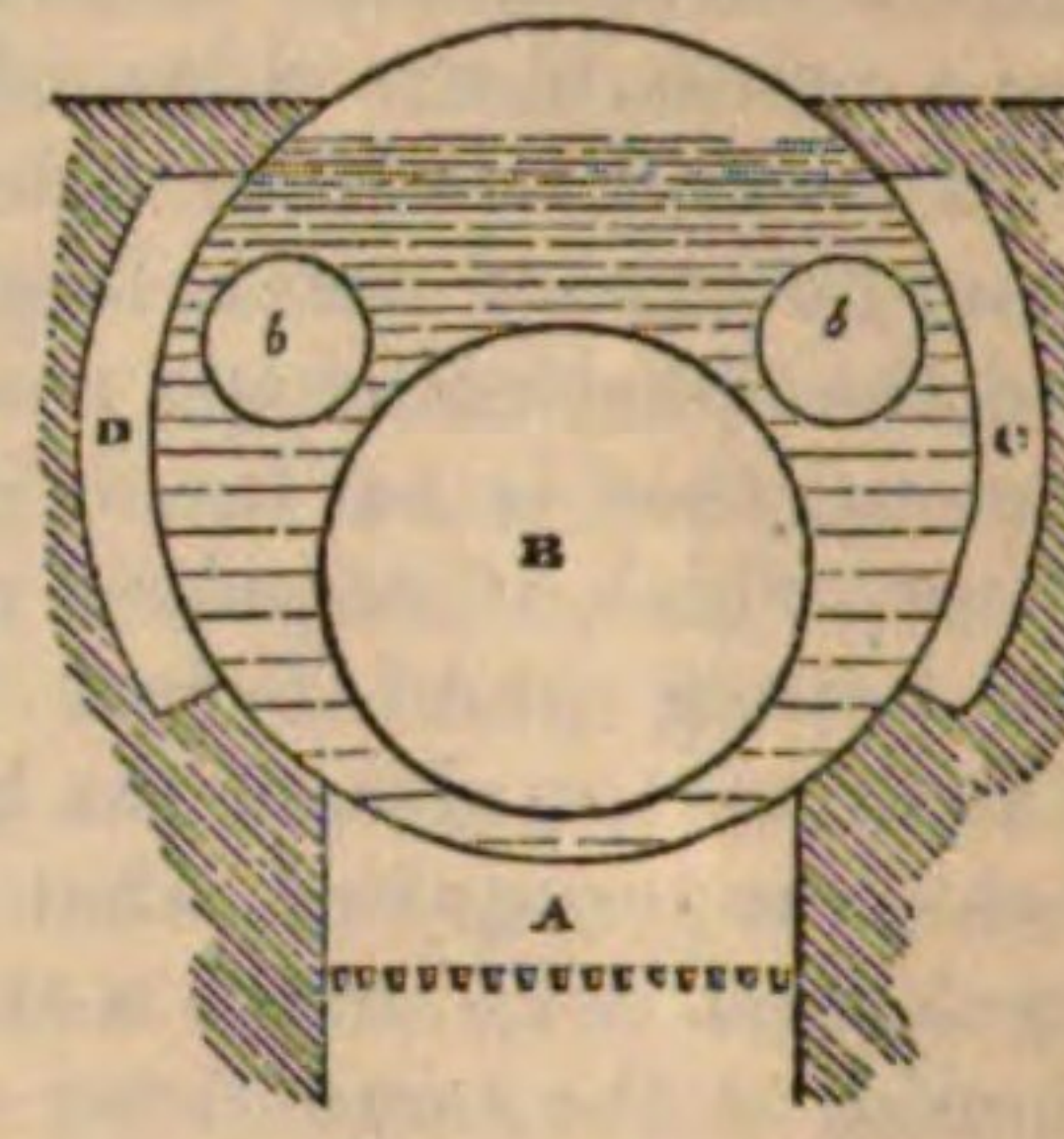


Fig. 215.



the whole length of the boiler, and expose a greater quantity of surface of water to the action of heat, in proportion as the tubes are small and numerous. These tubular-flued boilers are at the present day extensively used. They economize space, and, with a small exterior surface of boiler, generate a large quantity of steam. They are much used in Cornwall, in marine boilers, and in locomotive boilers.

In these boilers a large surface is still exposed to the cold air, and the brick-work in which the fire is placed radiates off a considerable portion of heat, which is lost. To remedy this evil, the furnace has been so contrived that the fire is in the inside of the boiler. This was probably done for the first time by Smeaton, who succeeded in producing almost as high a proportion of steam from fuel as engineers of a more modern date. His portable-engine boiler is represented below, figs. 216, 217. The interior of this hay-cock boiler contains a hollow ball of cast-iron, in which the fuel is burned. Air enters by an aperture at the bottom, a large cast-iron pipe leads through the water to the door, and another pipe in the opposite direction passes through the water, conducting the products of combustion to the chimney, immediately round which is introduced the fresh supplies of cold water for replenishing the boiler.

Smeaton's
Boiler.

Fig. 216.

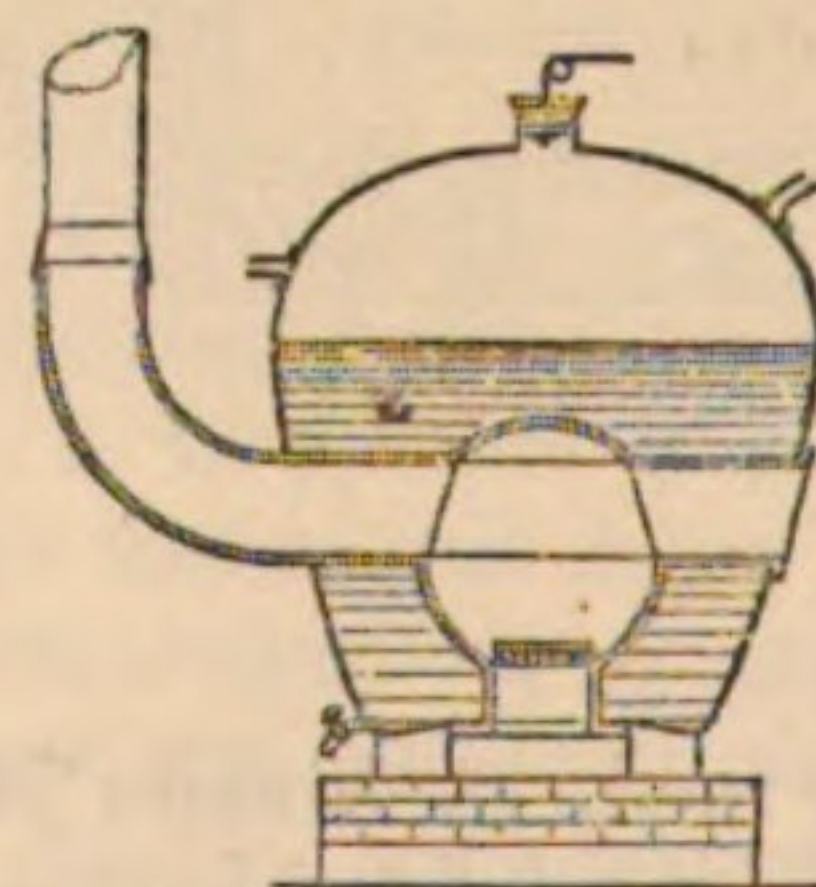
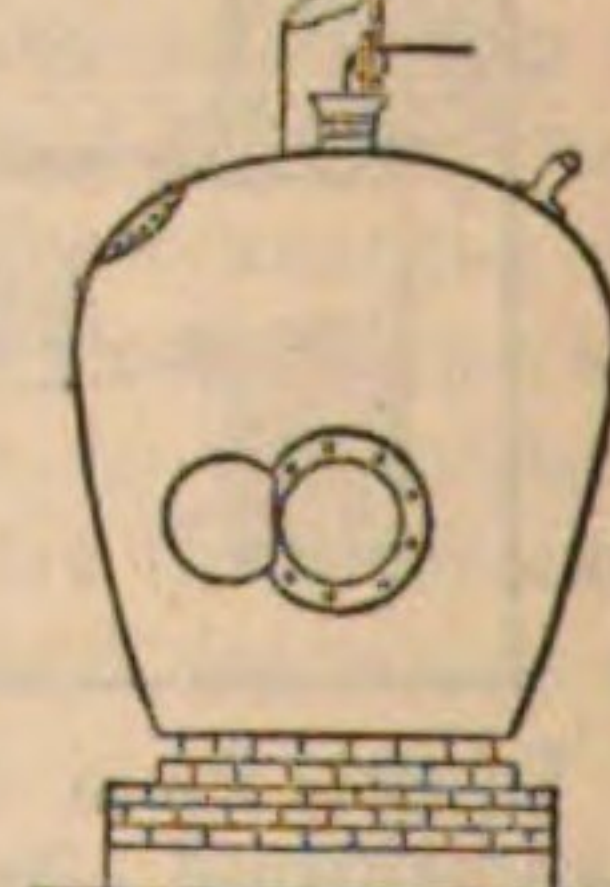


Fig. 217.



But a much better boiler than this, and one indeed which might bear comparison with many boilers of the present day, is one given by Mr Farey as the invention of an unknown author. In the centre of a large old-fashioned hay-stack boiler, figs. 218, 219, is placed a large round furnace, from which there passes a simple rectangular flue, winding round and round the

Steam-Engine Boilers.

boiler in spiral circuits till it reaches the outside, and thence passes to the chimney.

Fig. 218.

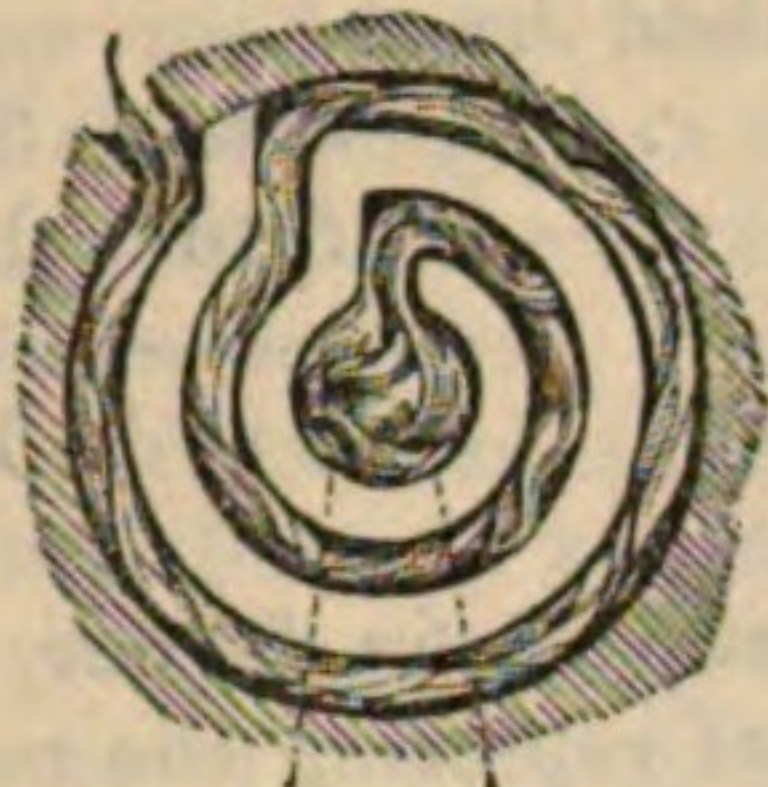
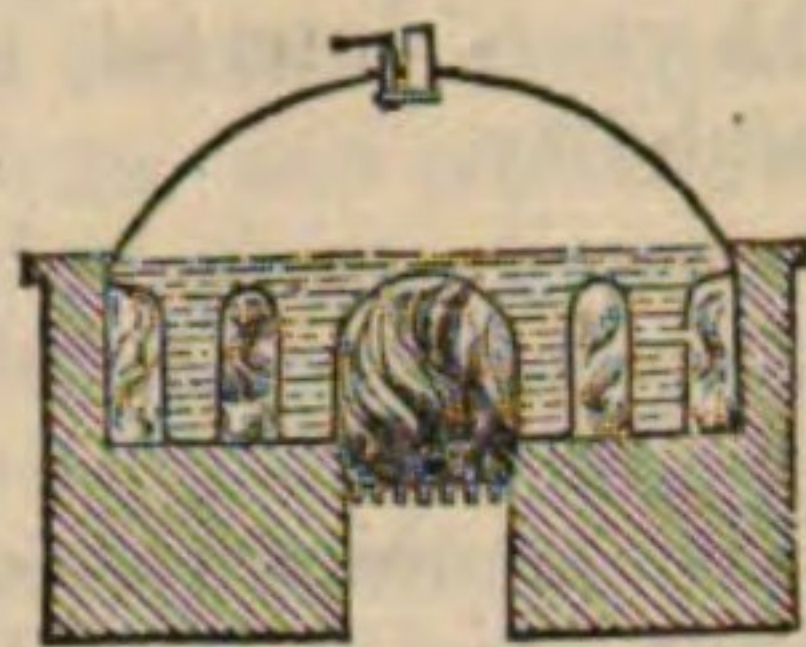


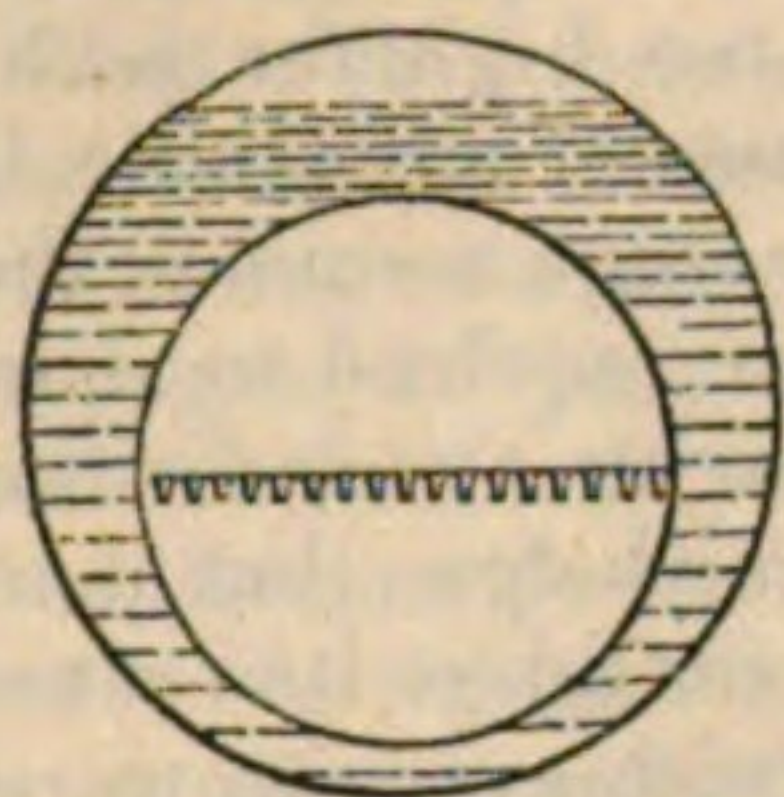
Fig. 219.



Boilers with interior furnace.

In the same way it has often been provided that the furnace should be in the interior of a cylindrical boiler, by placing another cylindrical tube of large dimensions in the interior of the outer case, to serve at once as furnace and flue. This was probably first done by Trevithick, the advocate of high-pressure engines in this country.

Fig. 220.



To the great central flue there have been sometimes added lateral flues on each side, for the return of the products of combustion, fig. 221. Thus, again, this internal flue has been made elliptical, fig. 222, a dangerous and weak form.

Fig. 221.

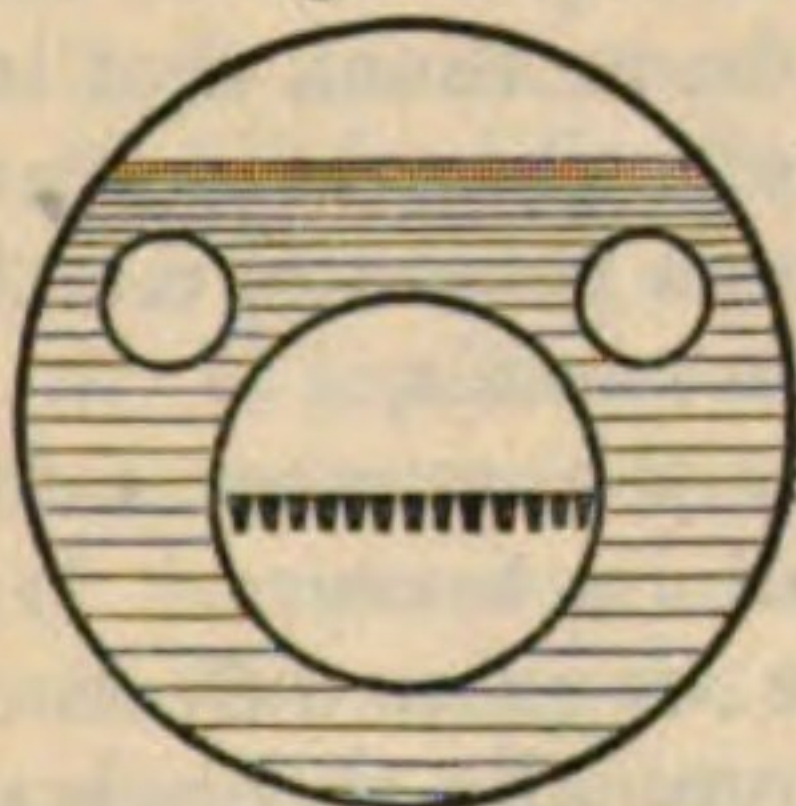
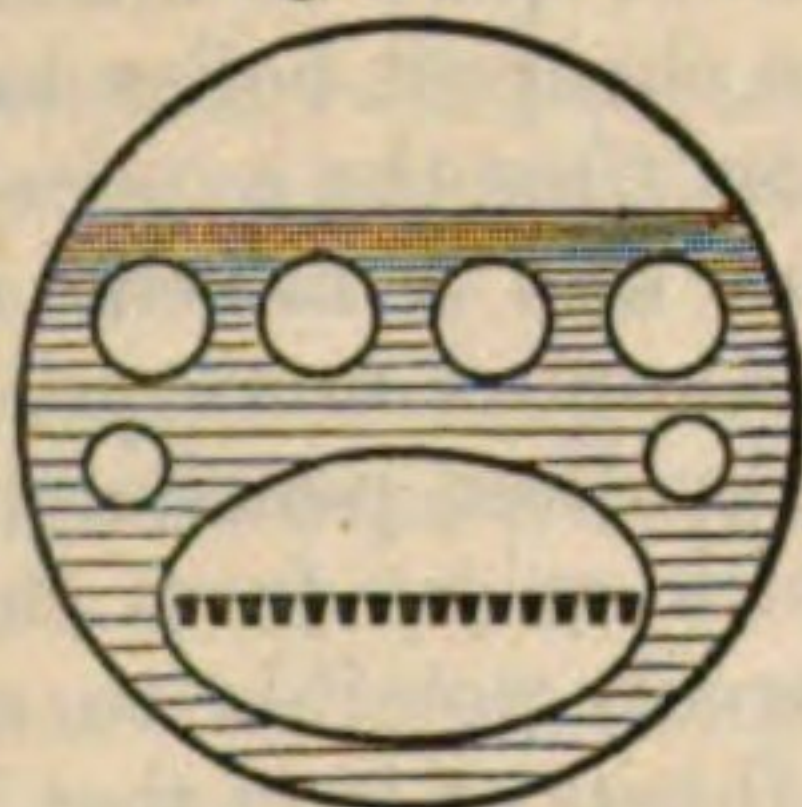


Fig. 222.



It is one of the faults of the boilers that have their fires in the internal tubes, that the ash-pit and interior of the furnace over the fuel are so confined, as to prevent that perfect combustion of fuel which may be obtained by a deep ash-pit, a large expanse of fire-grate, and a deep and wide furnace. These evils may, in some measure, be obviated by an internal flue of large dimensions; but this very large one is extremely dangerous, and liable to explosion. The evil has been remedied by the following species of boiler, where the fire is still surrounded by water, and gives ample room for most perfect combustion.

Fig. 223.

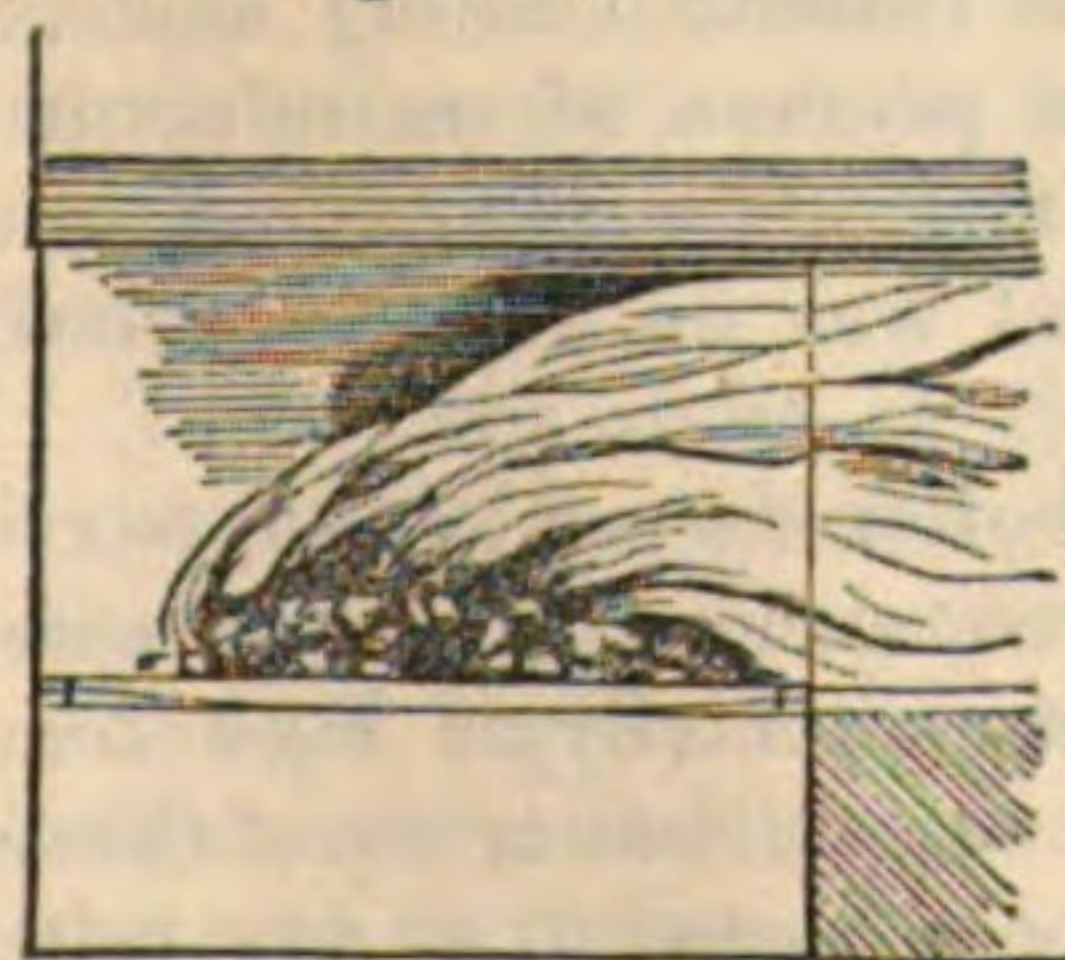
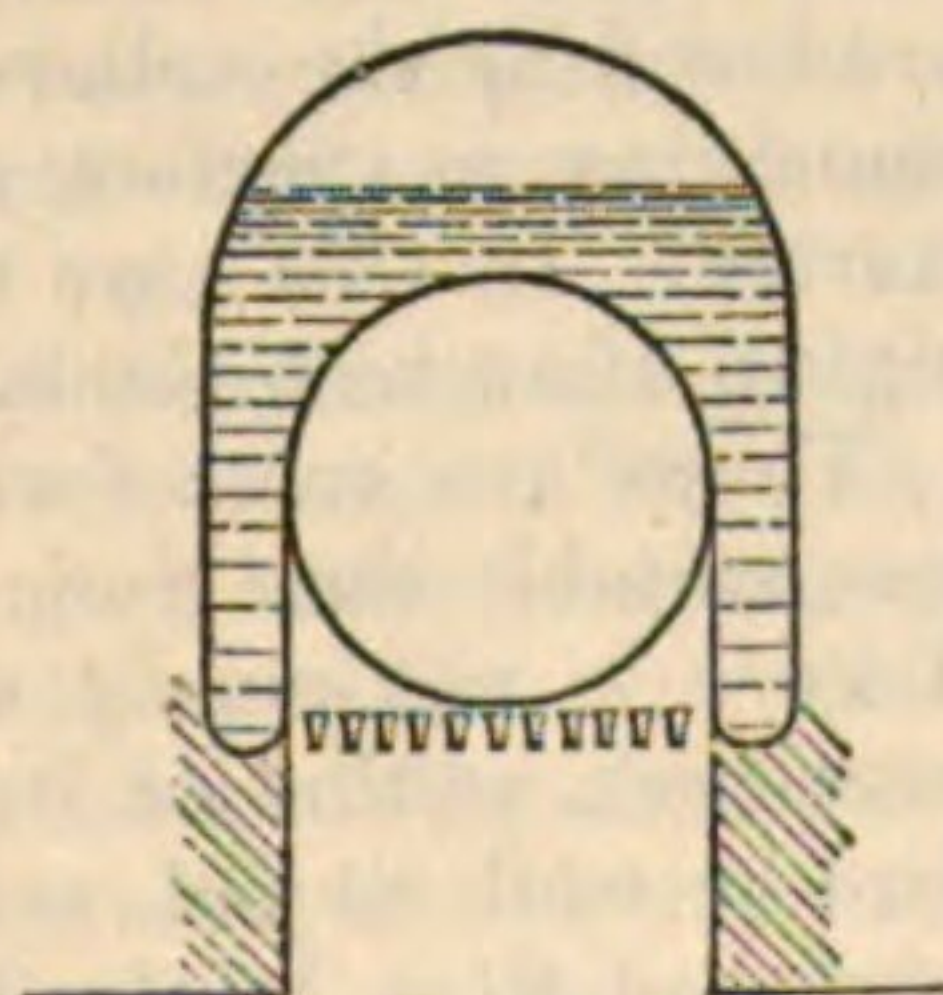


Fig. 224.



In this species of boiler, the tube opens out at the front,

so as to leave a semicircle or a semi-cylinder above the fire, and two vertical spaces, or "water legs," as they are called, which cover the fire on both sides; thus obstructing the heat that would otherwise pass away into the brick building, and at the same time covering a large and wide space of furnace bars, a deep ash-pit, and so ensuring adequate combustion. The internal surface of this boiler has been still further increased, by substituting for this single tube a number of smaller ones six inches in diameter.

Steam-Engine Boilers.

Fig. 225.

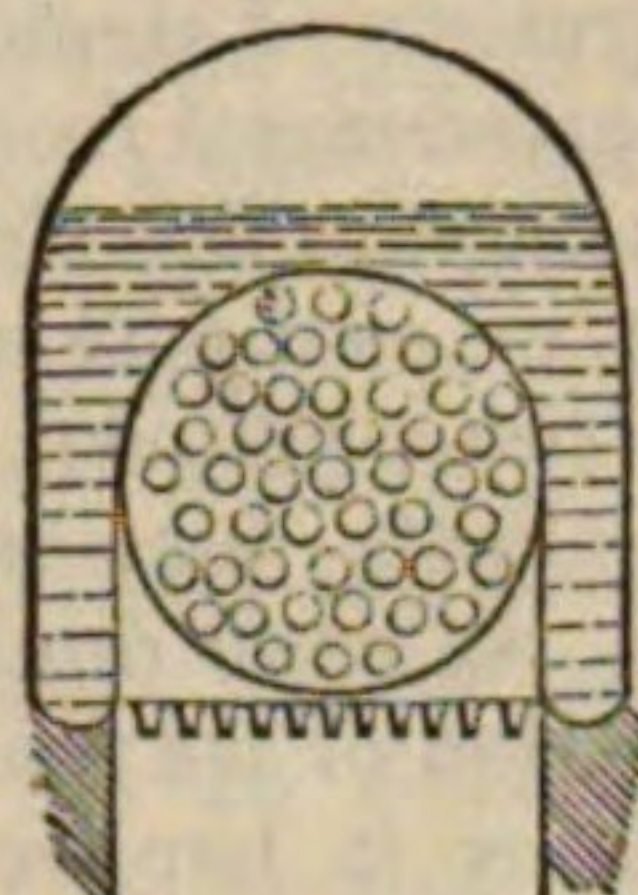
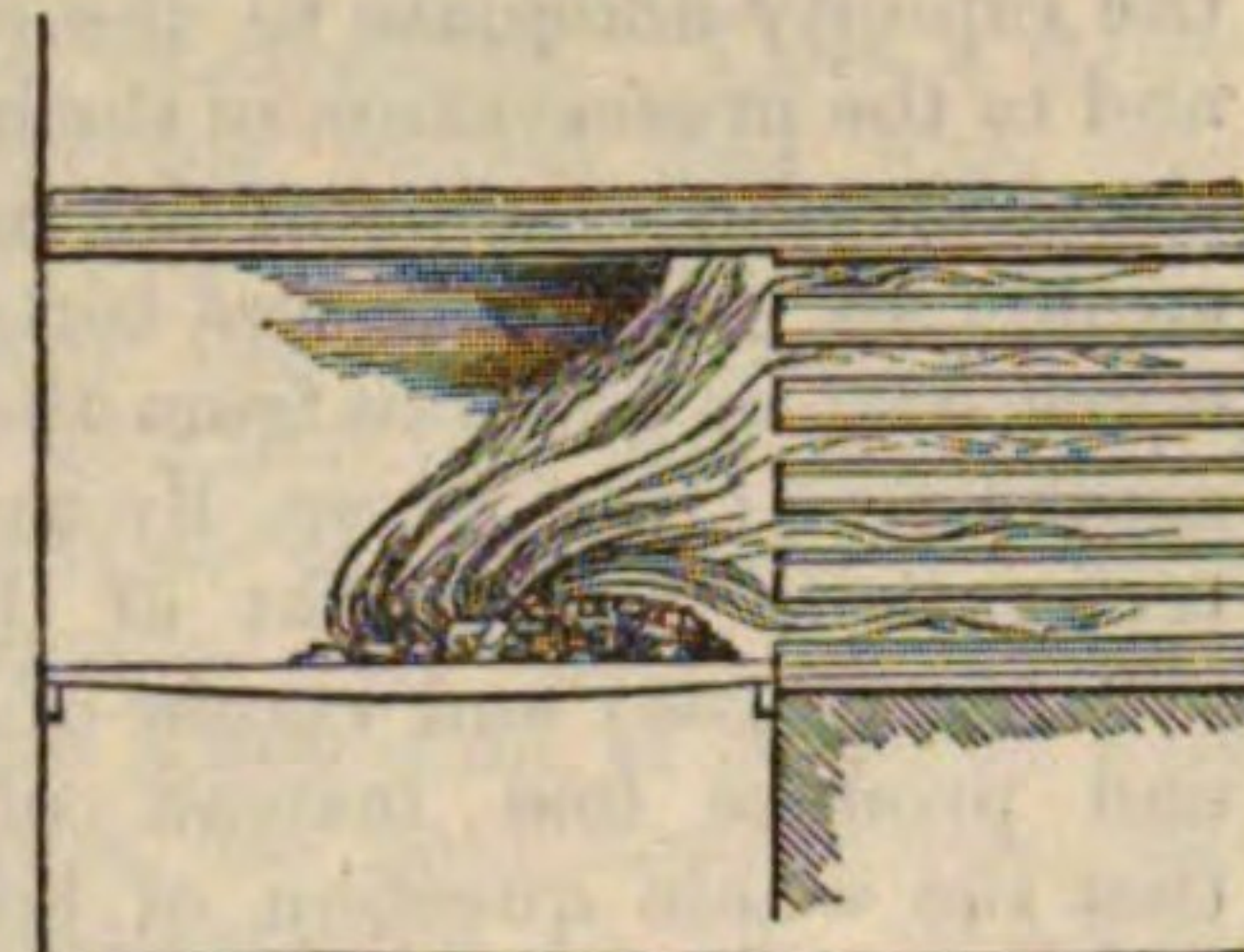


Fig. 226.



After passing through all these tubes, the flame and hot gases again return along the bottom and sides on the right of the boiler, and pass back on the other side to the chimney. A form of boiler similar to this is much used in Lancashire, and is called the Butterfly Boiler. It has the large internal flue, but wants the fire-legs, and in this respect is inferior to the former.

Fig. 227.

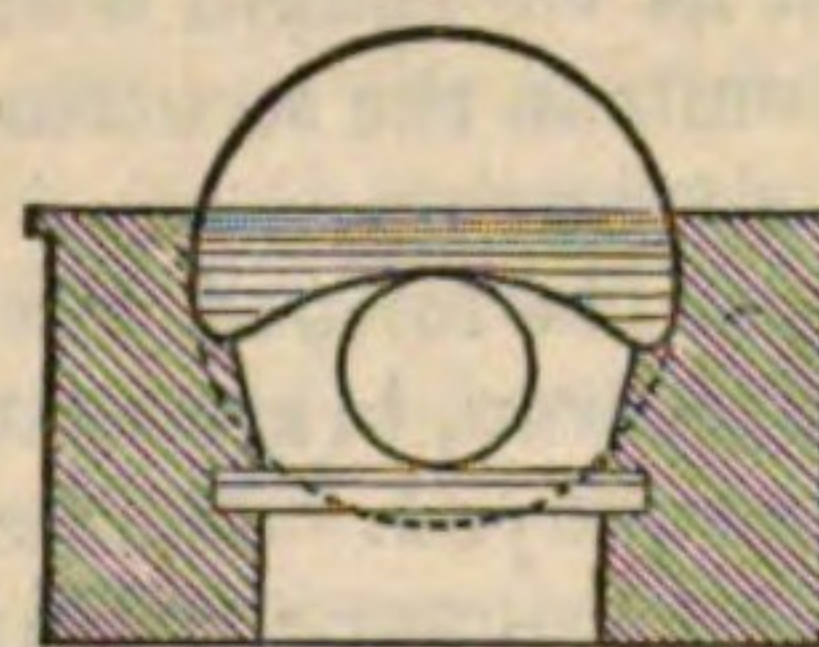
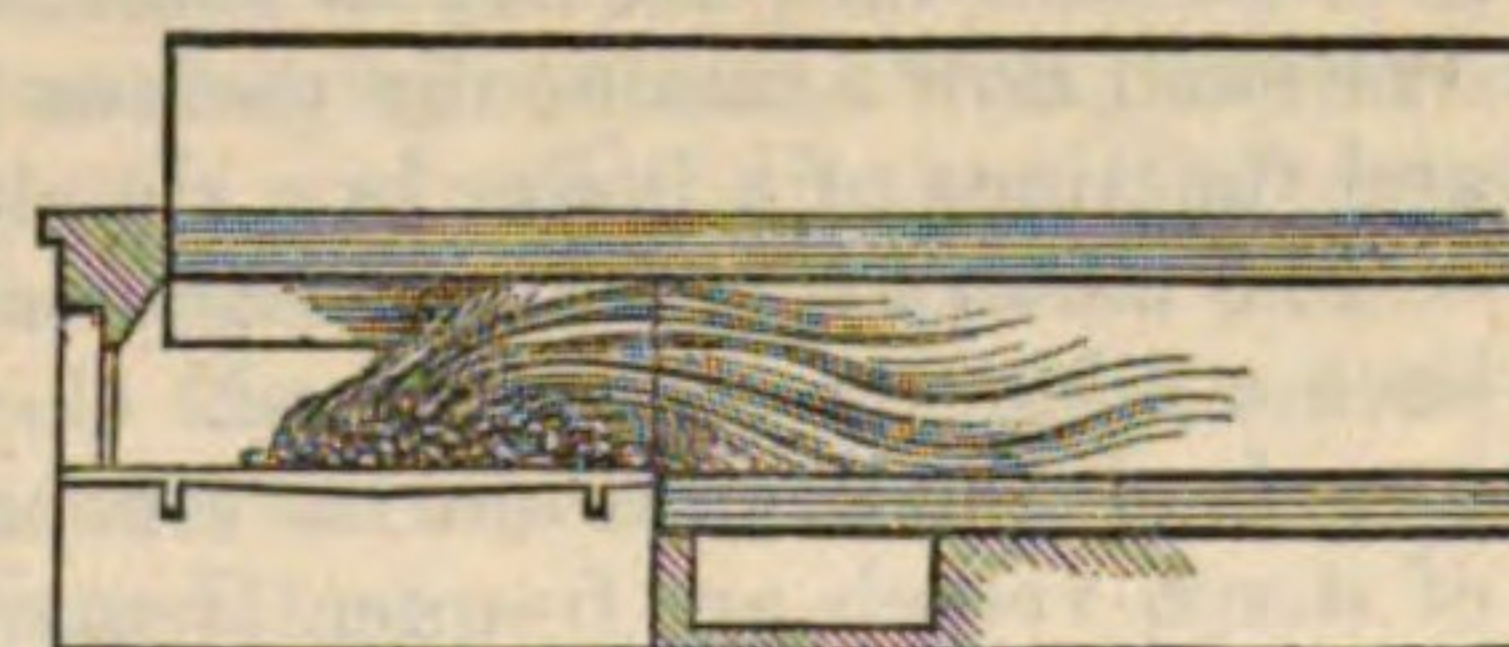


Fig. 228.



Those boilers, already described, are the practical forms in use among intelligent engineers. The varieties of boiler that have been invented, amount to some hundreds. The Patent Records of the present day teem with new and improved boilers; and yet it is a matter of constant complaint with engineers, that no great improvement has ever been made in boilers, but that as satisfactory results have been obtained from plain, simple boilers, of the kind used half a century ago, as from the modern and most complex forms.

The conclusion to be drawn from all that has been attempted or achieved in boilers is, we believe, the following: that there exist certain limits prescribed by the constitution of fuel, the nature of metals, and the properties of water and steam, which cannot be exceeded without incurring evils that greatly overbalance the partial gain. The best boilers that have ever existed have been those in which a large number of principles have been applied, and so adjusted in relation to each other as to gain the maximum, not of any one property, but of all the valuable properties, each in the degree of its individual importance. The first cost of the boiler must not be rendered too great, or that will neutralize the economy of using it: the space to which it is confined may be as small as possible; but if that be produced by intricacy of construction, the loss may surpass the advantage. Then, again, if complex and confined, it may be impossible to cleanse or to repair the boiler; and therefore it must be remembered, that, unless easy access can be gained to every part of a boiler, and of its flues, that boiler will soon become totally useless. Then it is further demanded

Steam-Engine Boilers.

of a good practical boiler, that, if one part should be damaged or give way, the whole should be so constructed that the damage done to that part must not endanger the rest. An extensive heating surface is to be obtained for economy's sake; but that large surface must at the same time remain unimpaired to resist bursting; a property to a certain extent inconsistent with extensive surface. The surface which is thus spread as widely as possible, so as to apply the fire to the water through every part of its mass minutely and in great subdivisions, if extended beyond a certain degree, will not have over it a body of water capable of conducting heat from it with the rapidity adequate to the rapid generation of steam, and to the preservation of the intensely heated metal from the destructive action of the fire. Then, again, it is desirable to have long and tortuous flues, to extricate as much heat as possible from the fuel and the products of combustion; but these, by their very length, may interfere with the draught of the chimney, so as to diminish the efficacy and vigour of the combustion of the fuel, and produce loss instead of gain. Thus it happens that the whole question of boilers is an exact and judicious combination and adjustment of parts, so as to obtain each of these many points in that degree which is most advantageous for every one of the other qualities, and of all of them together. The question is a practical one of no common difficulty.

It is principally by the collection of facts, of accurately recorded statistics of boilers, of the practical experience of the most eminent engineers, that we can gather data for the solution of the question of the best boiler. We are not without such data, although it is much to be regretted that they are not so abundant as we should wish. We shall now examine the various points in the structure and functions of a boiler in a simple succession.

Materials of which boilers have been formed.

The materials of which a boiler should be formed, have been a subject much discussed. Copper, iron, brass, cast-iron, lead, and even stone, have been employed. Boilers of steam-vessels are frequently made of copper. Many steam-boilers have been made of cast-iron, and have lasted long, and been very efficient under careful management. Wrought-iron-plate boilers are very common in this country; and in America have been much used, with cast-iron ends or heads of considerable thickness. The boilers of locomotive engines have the interior, which is exposed to the direct impact of the flame, formed of copper, and sometimes partly of brass; the exterior of the boiler being wrought-iron. Cast-iron boilers were extensively used under Mr Smeaton, towards the end of last century; and when used with care, were employed with advantage where fuel was plentiful, from their cheapness. A stone exterior jointed with cement, the interior being copper, where subject to great heat, and when the steam has scarcely any greater pressure than the atmosphere, has also been employed; and a dome or cupola of lead was often seen, in earlier times, when the art of working iron-plate was less common than it is now, forming the cover of the antiquated Hay-stack Boiler, which, in these times, the "Waggon" of Watt has almost entirely removed out of use.

Copper. Its advantages as a material for boilers.

Copper is the best of all substances for steam-engine boilers, in a mechanical point of view. That it is not best in a mercantile point of view, is proved by the almost universal use of wrought-iron boilers. Yet it is difficult to see why this should be the case, if we remember that copper lasts for ever, and is worth, when old, nearly two-thirds of its first cost, besides being a much better conductor of heat, and so saving fuel and space. The labour, too, of making a copper boiler is no greater than an iron one. The relative value of these materials for boilers may be stated thus:—

The efficiency of a copper boiler in generating steam, is to that of iron as . . . 3 to 2
The cheapness of equal weights of copper and iron boilers, are as . . . 30 to 130
The value of old materials diminished by 15 years' interest, is . . . 4 to 3
Durability, . . . 5 to 1

30 to 13

Steam-Engine Boilers.

Copper and iron compared.

The combination of all these ratios is in favour of copper; and if we add the trouble of replacing the new iron boiler, and detaching it from all its connexions, five times for once in the case of copper, the scale still further preponderates on the same side. We must look, therefore, for the explanation of the general use of iron to the state of mercantile affairs, and the value of money in a commercial community. It proves that a certain loss, within 15 or 20 years, in a proportion of 12 to 1, is considered preferable to an original expenditure of four times the amount of capital; showing either that the price of money is too high for such an investment, or that the contingencies of mercantile life are too great to allow the risk of so large a sum as the value of a copper boiler for the period required to reimburse the proprietor. Rich governments and individuals have not failed to profit by this knowledge; but it may be noticed of a government which considers its tenure of office insecure, that it does not furnish even its war-steamers with copper boilers, as that would involve the expenditure of a large sum by which their successors would profit. So also the man who is shortened in means, but hopes to be rich enough by the time one boiler is done to get a new one; or who does not know whether he shall be solvent so long as to see the boiler out; or who, at any rate, cannot spare so much money at once—procures at once the cheapest boiler he can; and finds, as usual, that in a short time the expenses of coal and of repairs have drawn from him a heavier than the usurer's percentage. All this applies more peculiarly to steam-vessels.

Reasons for the general preference of iron.

Another peculiarity of copper is the greater safety which arises from the uniformity of its texture. It is scarcely possible to account for the singular differences of sheets of iron that have passed nominally through the same processes of manufacture. One plate will become deteriorated by heat in half the time of another apparently identical. The parts of the same plate are frequently heterogeneous. The consequences of this heterogeneity are serious, and sometimes destructive: a single plate in a series gives way, and, having broken the chain of connexion, the whole fabric is destroyed; or a latent crack develops itself in the place most difficult to restore; or one plate, or a part of it, is burnt through when all the rest remains sound. All this tells in favour of copper. The matter of the copper is very nearly homogeneous: its durability is nearly uniform, if it is not made too thick. We have examined the part of a copper boiler exposed to most intense heat after years of action, and found, when the soot was cleared away, the smooth shining surface, produced by the rollers in the process of manufacture, remaining as perfect as the day after the boiler was started. In this case the metal was no more than one-eighth of an inch thick.

Greater safety and durability of copper boilers.

There are some forms of boiler for which copper is less suitable than iron. The strength of copper to resist flexure is not nearly so great, especially at high temperatures, as that of iron. A copper boiler must therefore be well stayed, and if there be round, or any other unstayed flues in the boiler, they cannot be of more than a foot in diameter without incurring danger; they will readily collapse or bend. This caution in regard to

Steam-Engine Boilers.

copper being given, it may be unhesitatingly recommended in point of safety, durability, and ultimate economy.

Experiments of the Franklin Institute on the strength of boiler materials.

In the article STEAM, we have already introduced our readers to the important experimental researches of the Commission of the Franklin Institute in America, concerning the structure, phenomena, and explosions of steam-boilers. We shall, in another place, present the results of their investigations of the causes of explosion. But there is a branch of the investigation undertaken by the committee, which is of importance to our present enquiry. It regards the strength of the materials of steam-boilers; a subject not before satisfactorily examined; and relates more immediately to the effect of high temperatures on the cohesive attraction of the particles of metals; an enquiry essential to our knowledge of the manner in which the known strength of metal, when cold, may be altered when, in a boiler, it is subject to the action of a fierce fire. The sub-committee to whom this subject was intrusted, were men of great practical skill and eminent scientific attainments. Professor Walter R. Johnson, Benjamin Reeves, Esq., and Professor A. Dallas Bache, were the members to whom the enquiry was committed; and it has been carried on with a degree of judgment in its arrangements, and of precision in the experiments, which warrant our implicit confidence in the results, and deserve our sincere thanks for the valuable additions made to our knowledge of this important and difficult subject. The importance of the branch of enquiry committed to these gentlemen, may be judged of from the following statement of its principal branches.

1. What is the absolute tenacity of rolled boiler iron at ordinary temperatures, and how great the irregularities to which it is liable?
2. A similar determination for copper boiler plates.
3. What effect is produced on the tenacity of these boiler plates by change of temperature?
4. What is the effect produced on the tenacity of iron by various processes of manufacture, such as wire-drawing, hammering, or rolling into bars or rods?
5. What are the comparative tenacities of boiler plate made from different mixtures of crude iron and from refined irons?
6. What is the comparative value of sheet iron manufactured by the processes of puddling, blowing, and piling respectively?
7. What is the effect of piling, into the same slab, iron of different degrees of fineness?
8. What is the comparative tenacity of rolled iron in the longitudinal, diagonal, and transverse directions of the rolling respectively?
9. What is the influence of frequently repeated heating on the plates of a boiler?
10. What relation exists between the force that will produce a permanent elongation in boiler plate, and that which will entirely overcome its tenacity?
11. What amount of elongation may the several kinds of metallic plates undergo before fracture?
12. What is the effect of rivets on the strength of a boiler?

These are some of the many important subjects of experiment undertaken by the committee. They have discharged the duties devolved upon them in a manner which is highly honourable to themselves, and which reflects great credit on the institution and the country that has sent forth into the world so valuable a contribution to practical science. We regret that the limits of this article will not permit us to enter into the experimental details and subsidiary enquiries connected with the ex-

tensive and laborious investigation; details which are always ingenious and instructive, and will amply repay the minute study of the mechanical philosopher or engineer as a valuable body of experimental truth. But, although we cannot convey to our readers the pleasure we have enjoyed in the perusal of these interesting records, we should do them and our subject injustice did we omit to convey to them the general conclusions which have been obtained.

Strength of Copper Boiler Plates.—The experiments upon this subject were very numerous. 32° being taken as the standard, it was found that the increments of heat always caused a diminution of strength. Thus, a stripe of copper, capable of carrying 10,000 lbs., was only capable of carrying 7,500 lbs. when heated to a temperature of 500°; while at 820° the same bar could support no more than a tension of 5,000 lbs, and at 1200° a visibly red heat in day-light no more than about a tenth part of the strength remains. By these experiments the law which connects the diminution of cohesion with the increase of temperature has been accurately determined, and it appears conformable to the following simple expression,

$$\left(\frac{t'}{t}\right)^3 = \left(\frac{d'}{d}\right)^2$$

when

$$\text{Log. } d' = \frac{3}{2}(\text{Log. } t' - \text{Log. } t) \text{ Log. } d$$

by means of which the diminution of strength having been ascertained for one temperature, it may be found for every other according to the following rule. From the logarithm of (t') the temperature (reckoned from 32°) of the diminution sought, subtract the logarithm of a given temperature, (t) and multiply three halves of the remainder by the logarithm of the known diminution (d) of strength at the latter temperature, and the product is the logarithm of the required diminution at the temperature assigned.

The following table exhibits the close accordance of the experiments with this law.

Table of Diminution of Strength of Copper Boiler Plates when heated. Their standard strength at 32°, being 32,800 lbs. per square inch.

	Temperature above 32°.	Diminution of Strength.		Temperature above 32°.	Diminution of Strength.
1	90°	0.0175	9	660°	0.3425
2	180°	0.0540	10	769°	0.4398
3	270°	0.0926	11	812°	0.4944
4	360°	0.1513	12	880°	0.5581
5	450°	0.2046	13	984°	0.6691
6	460°	0.2133	14	1000°	0.6741
7	513°	0.2446	15	1200°	0.8861
8	529°	0.2558	16	1300°	1.0000

We are, therefore, warranted in admitting the conclusion, that the square of the diminution of strength varies with the cube of the temperature.

Hence we learn, that between the temperature of freezing and boiling water copper loses 5 per cent of its strength; that at 550° it loses about a quarter of its strength; at 850° the half of its strength; and at 1330° loses all its strength, becoming a viscid, granular, soft, incohesive, substance; although it does not actually melt until it attains nearly 2000°. These phenomena in copper are strikingly at variance with the phenomena exhibited by iron at the same temperatures.

In this substance the remarkable anomaly was discovered, that the additions of heat, instead of weakening the metal, as we should have expected, and as was found

Steam-Engine Boilers.

Steam-
Engine
Boilers.

to be the case with copper, actually increased its strength, so that iron plate at 550° above the freezing point was 16 per cent stronger than when cold. After this point the strength began to diminish rapidly, so that this point appears to be the temperature of maximum strength. It was assumed as the standard strength, on both sides of which the strength was found to be diminished both by heat and cold. The strength diminishes rapidly with increments of temperature, after passing the maximum at 570°: thus,

At 32° to 80° the tenacity was	= 56,000 lbs. or 1-7th below its maximum.
At 570°	= 65,500 lbs., the maximum.
At 720°	= 55,000 lbs., the same nearly as at 32°.
At 1050°	= 32,000 lbs., nearly $\frac{1}{2}$ of the maximum.
At 1240°	= 22,000 lbs., nearly $\frac{1}{3}$ of the maximum.
At 1317°	= 9,000 lbs., nearly 1-7th of the maximum.
At 3000° iron becomes a fluid.	

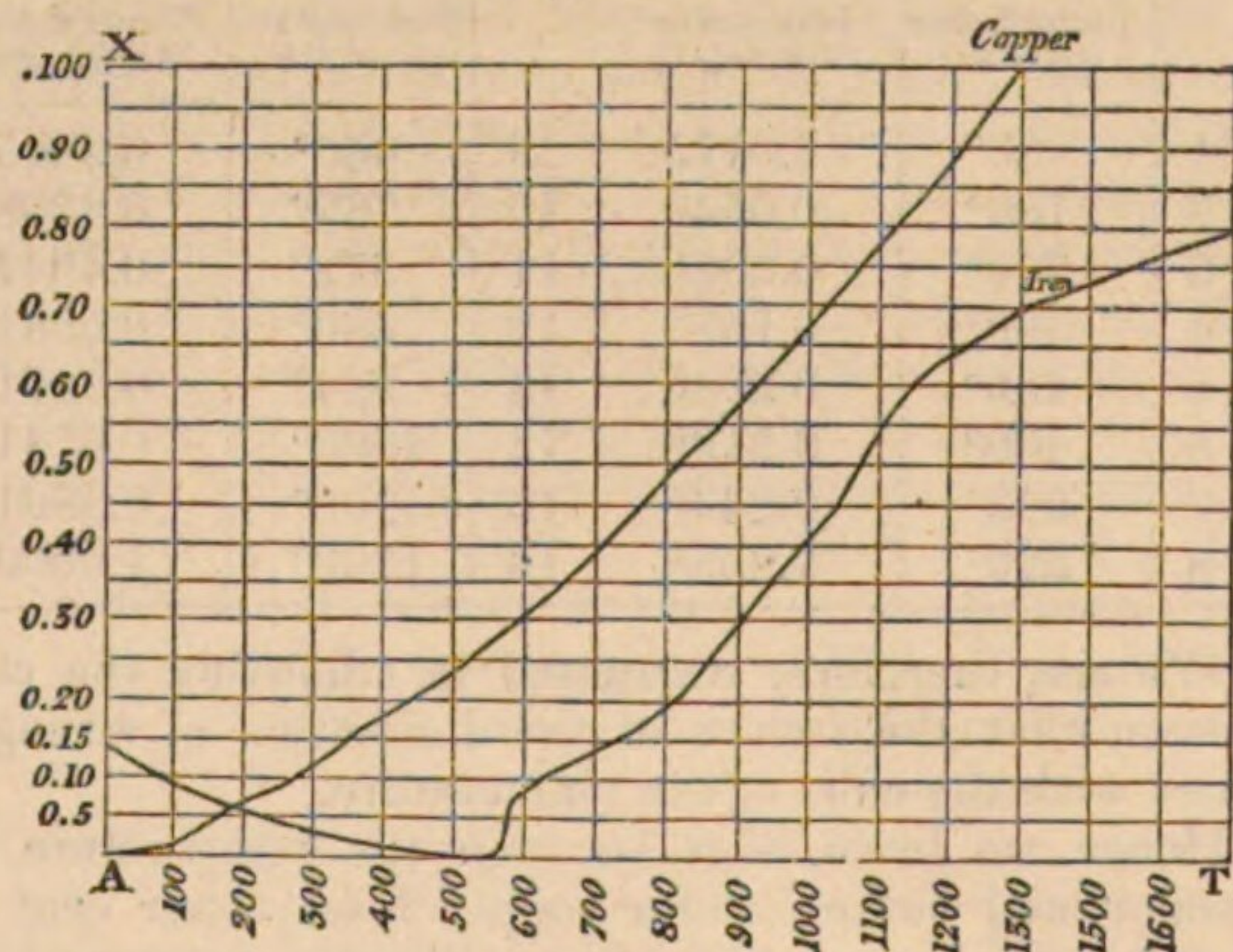
The following is a table of a series of these experiments.

Table of Experiments on Iron Boiler-Plate at High Temperatures; the Mean Maximum Tenacity being at 550° = 65,000 lbs.

Temperature observed.	Diminution of Tenacity observed.	Temperature observed.	Diminution of Tenacity observed.
550°	0.0000	824	0.2010
570°	0.0869	932	0.3324
596°	0.0899	947°	0.3593
600°	0.0964	1030°	0.4478
630	0.1047	1111	0.5514
562	0.1155	1155	0.6000
722	0.1436	1159	0.6011
732	0.1491	1187	0.6352
734	0.1535	1237	0.6622
766	0.1589	1245	0.6715
770	0.1627	1317	0.7001

The law of variation of the strength of iron and of copper by temperature may be easily illustrated by the following curves, of which the horizontal ordinates are temperatures, and the vertical abscissæ are diminutions of strength.

Fig. 229.



The temperatures are measured from the origin A towards T. The total strength being = AX = 1000, the diminutions of strength are represented by the fractions of A X measured from A towards X. These curves represent to the eye very distinctly the characteristics of the metals. The line for copper, rising from zero at A, shows, by continual recession from its maximum AA, the continual and regular diminution of strength by

increased temperature according to the law already stated. The line representing the iron, on the contrary, having its origin 15 per cent above A, descends and shows an increase of strength until it reaches a maximum about 500°, whence it suddenly rises, showing a very rapid diminution of strength up to 1000°, when again it changes, turns outwards having a point of inflection beyond which it may be carried to a great distance, while at last it becomes liquid between 2000° and 3000°.

The next branch of the enquiry was, how the strength of iron is affected by the mode of its manufacture, and by the different states in which it is used, as in bars, in wire, or in plates, produced by hammering, drawing, or rolling. The following are the results of several experiments on the tenacity of different kinds of iron, at ordinary temperatures.

Iron Wire, diameter	0.333	84,186 lbs.
	0.190	73,888
	0.156	89,162
Russian Bar Iron,		76,069
English Cable Iron, hammer-hardened,		71,000
English Cable Iron,		59,105
Lancaster Co. U.S.		58,661
Centre Co., U.S.,		58,400
Swedish Bar,		58,184
Salisbury Com., U.S.,		58,009
Tennessee Bar, U.S.,		52,099
Slit Rods,		50,000
Missouri Bar Iron,		47,909

No. 1. Pig iron, of the white fracture, produces the most cohesive bars.

No. 2. Pig iron, of a lively gray fracture, produces bars inferior to No. 1 by $1\frac{1}{2}$ per cent.

No. 3. Pig iron of a dead gray fracture, produces bars inferior to No. 1 by 2 to 3 per cent.

No. 4. Pig iron, of a mottled fracture, produces bars inferior to No. 1 by 5 per cent.

A mixture of all the kinds produces bars inferior to No. 1 by 5 to 10 per cent.

The difference between the strength of boiler-plate, cut lengthways and across, was found to be about 6 per cent in favour of the longitudinal over the crosscut.

Stripes cut longitudinally sustained 63,947 lbs.

Stripes cut transversely sustained 60,176 lbs.

Stripes cut diagonally sustained 53,925 lbs.

The specific gravity of iron boiler plate was found to range from 7.7922 to 7.6013., and to be at a mean value 7.7344.

The effect of repeated piling and welding was found to be a great increase on the strength of iron. The iron given in the preceding table, from the Centre Company's manufactory, whose strength when rolled amounts to 58,400, was found to be so much improved by piling four bars and welding twice, as to support a mean of 59,247 lbs., and to be so homogeneous that the highest did not differ from the lowest results by more than 3.4 per cent in the different specimens. Simple welding twice without piling, gave a result of 58,787 lbs.

It has been thought that by welding together different kinds of iron of different degrees of fineness, and then rolling it out, a valuable boiler-plate might be obtained. This was tried, and the highest result gave only 40,600 lbs.

The weakening effect of riveting is thus calculated from these experiments, being a diminution on the whole of $\frac{1}{3}$ of the original strength.

Strength of the stripe without riveting.	9290.
Strength of the remaining metal, deducting rivet-holes,	+ 5662.
Diminution of strength by rivet-holes,	- 3628.
Strengthening effect of rivets,	+ 679.

Steam-
Engine
Boilers.

Iron boiler
plate.

Its
strength as
affected by
the mode
of its manu-
facture, &c.

Steam-
Engine
Boilers.

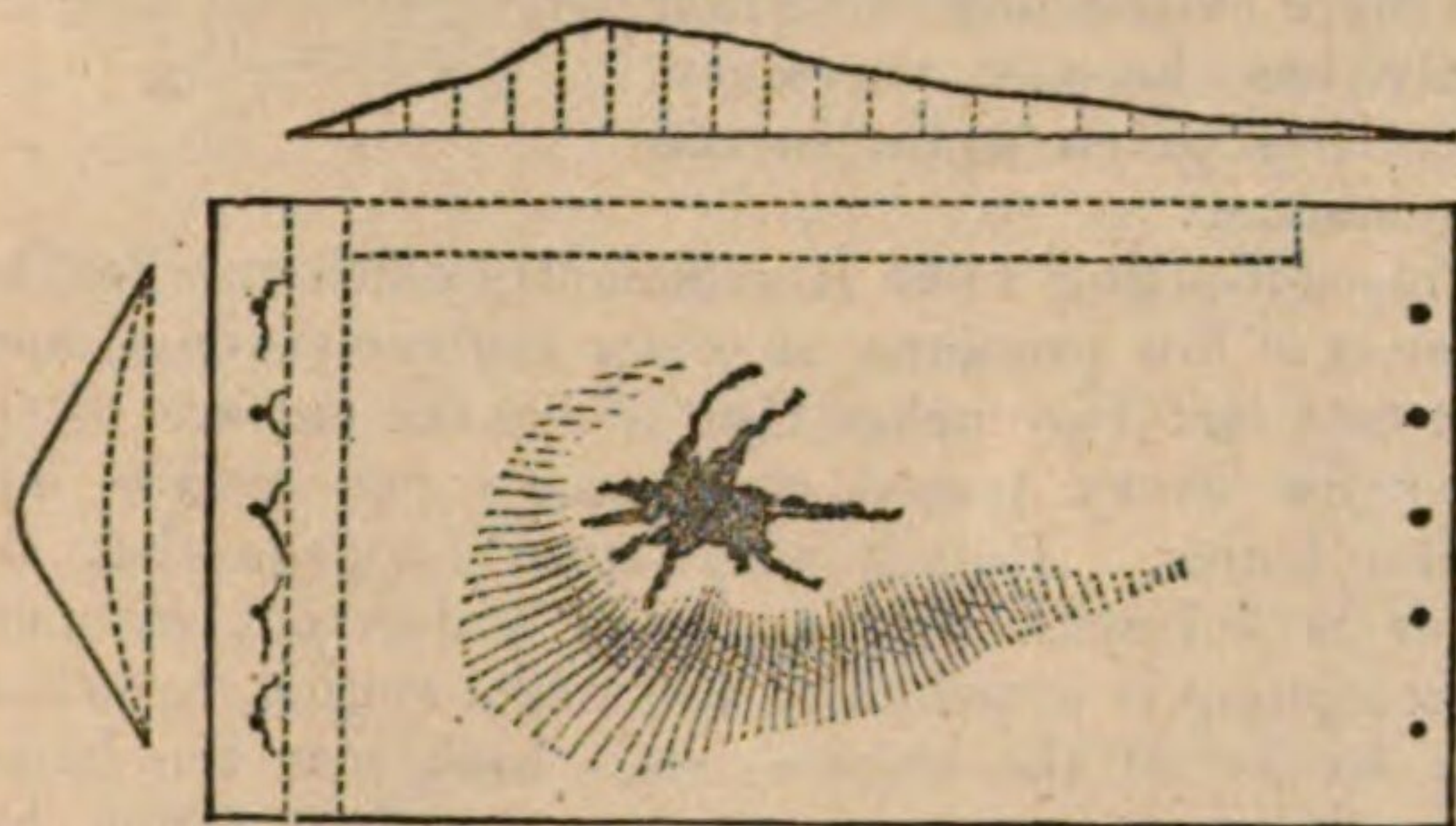
The effect of use and long exposure on the strength of boiler iron was found to be a great diminution of its strength, none of the specimens coming up to 50,000 lbs.

The effect produced by the accidental overheating of a boiler, was found to be the permanent reduction of its strength from 64,000 or 65,000 lbs., to 45,000 lbs. per square inch, being about $\frac{1}{3}$ d of the original strength.

The permanent extension produced on iron plate by weights much less than are required finally to overcome its cohesion, was a subject of careful examination. The extension began to take place in general when $\frac{3}{4}$ ths of the breaking weight were applied, and sometimes when only $\frac{2}{3}$ ths had been applied. The total extension varied between $\frac{1}{10}$ th and $\frac{1}{8}$ th of the total length, and was greater in the longitudinal than the transverse direction of the bar.

The following diagram of a fracture is highly instructive. The elongation transversely is $\frac{1}{10}$ th of the original dimension, and the curve, is $\frac{1}{4}$ th longer than the chord. The longitudinal direction of the fibres is in the line of the shortest dimension. It is evident that the diminution of

Fig. 230.



the thickness, previously to fracture, must have greatly weakened the plates of the boiler. This boiler plate was taken from that part of the boiler immediately over the fire, and had burst where sediment had collected, and excluded the water from contact with the boiler, so as to allow it to get overheated.

It is evident that the diminution of area at the point of fracture, which accompanies this stretching of the plate before fracture, must weaken the plate very greatly when it is exposed to strains that stretch it much beyond its initial length, this strain being about half the breaking strain due to the original thickness. This constriction or thinning out of the plate is observed to take place much more in thickness than in breadth, and to amount in iron to about $16\frac{1}{2}$ per cent of the whole area. It is remarkable, that the constriction was found less in heated than in cold specimens of iron, a result the reverse of that which we should have anticipated. The fractures at high temperatures were found to take place suddenly, and the surfaces of fracture presented appearances altogether different from those exhibited at low temperatures; the peculiarity of the fracture at high temperatures being, that the section is smooth and flat instead of jagged, fibrous, and irregular, and that it takes place directly across the plate, and tapering off at an angle of 45° , so that the separate fragments resemble "the edges of two mortising chisels." One result which we deduce from the American investigation is, that boiler iron cannot safely be trusted with a greater pressure than $\frac{1}{3}$ th of its standard maximum cohesion. Such are some of the valuable facts elicited by this transatlantic investigation. The experiments should be repeated in this country upon the different species of our own iron; and we have no doubt the subject will be taken up by some of those gentlemen who have prosecuted valuable researches on

the strength of metals; into which, however, they have not yet introduced the element of high temperature.

The increase of the strength of iron, with the increase of its temperature up to 570° , is a remarkable anomaly which should incite us to examine other metals, and metallic alloys, in a similar manner, for the purpose either of resolving this phenomenon into some general law of corpuscular force, or of setting it aside as a characteristic and distinctive property of that singular metal. To the practical man, this discovery is of importance, inasmuch as it has shown him a quality in iron, as a material for boilers, which may weigh strongly with him when he hesitates in choosing.

The comparative value of copper and iron boilers is materially affected by this enquiry. The great advantages of copper are its durability, its high conducting power, and the value of the old materials. It is by no means so strong as iron, being, when cold, $\frac{3}{4}$ ths of the strength of iron, and at 500° only about $\frac{2}{3}$ ths of the strength of iron. But thin iron decays so rapidly, that its strength to-day is no criterion of its strength to-morrow: it decays so rapidly, especially with the salt water of steam vessels, that its very strength at first is necessarily followed with subsequent danger; for an iron boiler having once borne a great pressure with impunity, will afterwards, when the rapid but unseen decay has insidiously eaten through the metal, be again subjected to the same ordeal by which it had been formerly proved; and although under apparently the same circumstances, it may yield to the strain, and produce the distressing consequences of a violent explosion. It is time alone, then, that is the great enemy of iron boilers, while the integrity of the copper will continue unimpaired for a quarter of a century. On the whole, we find that the following general result should limit our faith in the materials of boilers:—

Steam-
Engine
Boilers.

General
practical
result of
the en-
quiry.

Standard strength of boiler plate, . . .	55,000.
Strength after riveting, . . .	$\frac{2}{3}$.
Strength after heating and cooling in use, . . .	$\frac{2}{3}$.
Strain of permanent extension, . . .	$\frac{2}{3}$.

Greatest practical strength = $\frac{2}{3}$ of $\frac{2}{3}$ + $\frac{2}{3}$ = $\frac{8}{9}$ = $\frac{1}{6}$ nearly.

The greatest practical strength being $\frac{1}{6}$ th of the absolute cohesion, and the greatest practical strength, to prevent explosion, being four times more than any boiler should be ordinarily worked at, we have $\frac{2}{3}$ or $\frac{1}{2}$ of the standard strength of boiler iron, as its ordinary working pressure; 2,500. lbs. of extension on each square inch of cohesive action may, therefore, be assigned as the safe working strain of iron boilers.

To a steam-engine boiler there are many appendages, contrived for the purpose of facilitating the regulation of the quantity of fuel or of water, the intensity of combustion, the elasticity of the steam. One of the most simple and essential of these is a water-gauge. Water-gauges are of three kinds, glass-gauges, stopcock-gauges, and float-gauges.

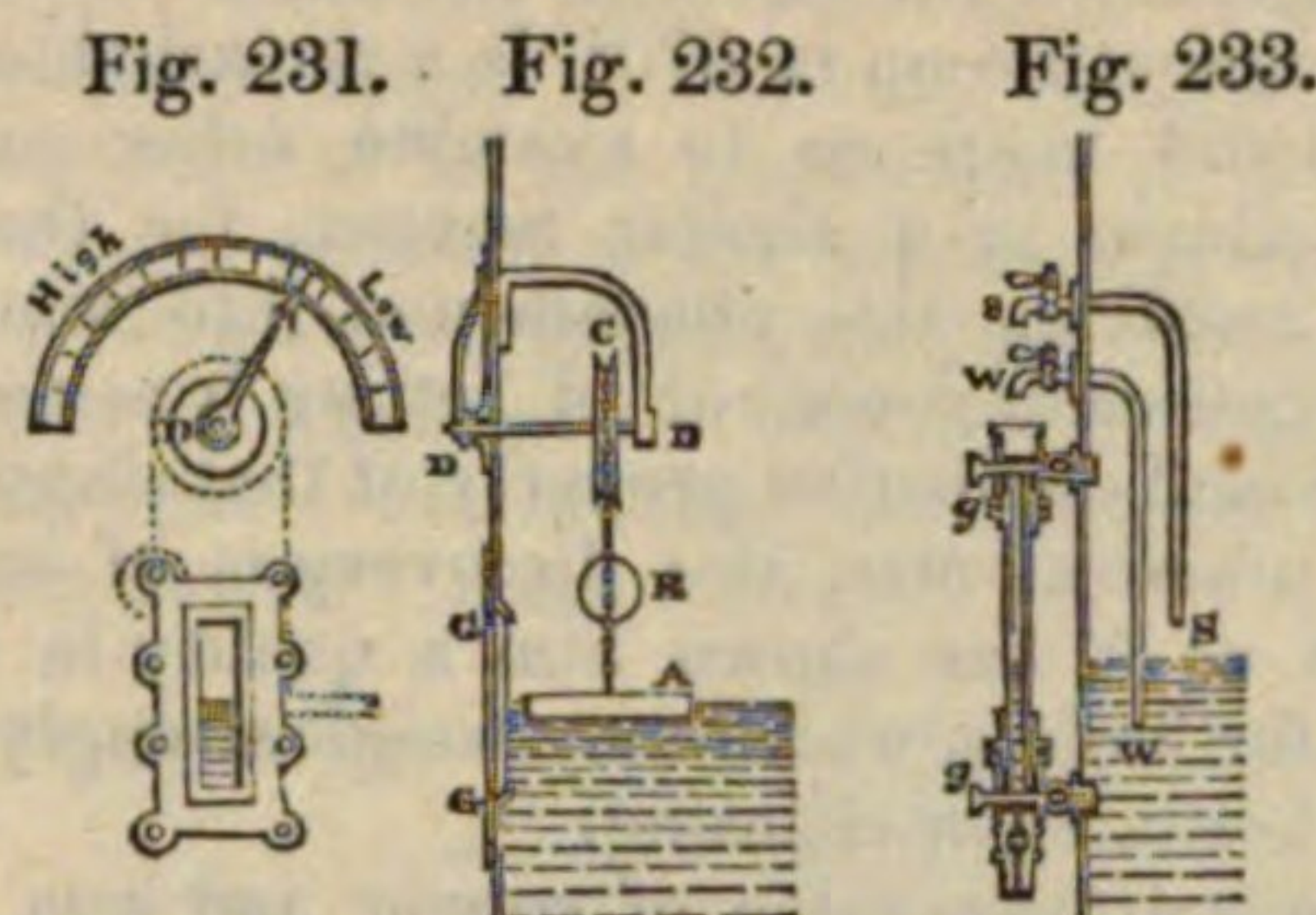
The glass-gauge is of two kinds, plane and tubular. A plane glass-gauge consists simply of a small window in a boiler, of very thick glass, inserted at the place up to which the water should rise in the boiler. The tubular glass-gauge is a small pipe of glass about half an inch in the internal diameter, and an inch and a quarter in thickness. It is placed on the outside of the boiler, and communicates at the top and bottom by stopcocks with the interior of the boiler; the higher stopcock enters the boiler among the steam, a little above the upper surface of the water, and the lower stopcock enters a little below the surface of the water, so that the water, standing in the glass tube on the same level with the water in the boiler, shows itself in the glass tube to the attend-

Append-
ages to
Steam-
Boilers.
Water-
Gauges.

Steam-
Engine
Boilers.

Water-
Gauges.

ant. These two gauges are shown in the accompanying drawings.



In figs. 231, 232, G is the window of very thick glass, set in a brass frame with a cement of red and white lead, after which, the frame is firmly bolted on the front of the boiler, at the aperture to which it is fitted. *gg*, fig. 233, is the tube glass-gauge, communicating with the water below and the steam above. There are shown in the same figure two other kinds of gauges. *Ww* is a tube open at both ends, regulated at the external termination by a stop-cock, but passing into the boiler, so that the other end descends below the surface of the water in the boiler. Another gauge-tube *Ss* is of similar construction, and is placed higher up, so that the end *S* is open in the boiler among the steam. By this means the engineer has it always in his power, on opening these cocks successively, to determine whether there be an excess or deficiency of water in the boiler; for, the orifices of the tubes in the inside of the boiler are adjusted in such manner, that when the water is at the proper level, it covers the orifice of the lower one, but does not reach the orifice of the upper one. In this state steam will issue from the upper pipe, and water from the lower pipe; but if it should be found that water issues from both, the water is too high, and if steam from both, there is too little water in the boiler. Another species of gauge is also shown in figs. 231, 232. It consists of a float *A* resting on the surface of the water in the boiler, to this is attached a chain, which passes over a pulley *C*, and carries at its other end a counterweight *R*. The pulley is fixed on an axle *DD*, which passes through the boiler and carries on its outer end an index. The index shows, by means of a dial-plate, the state of the water in the boiler.

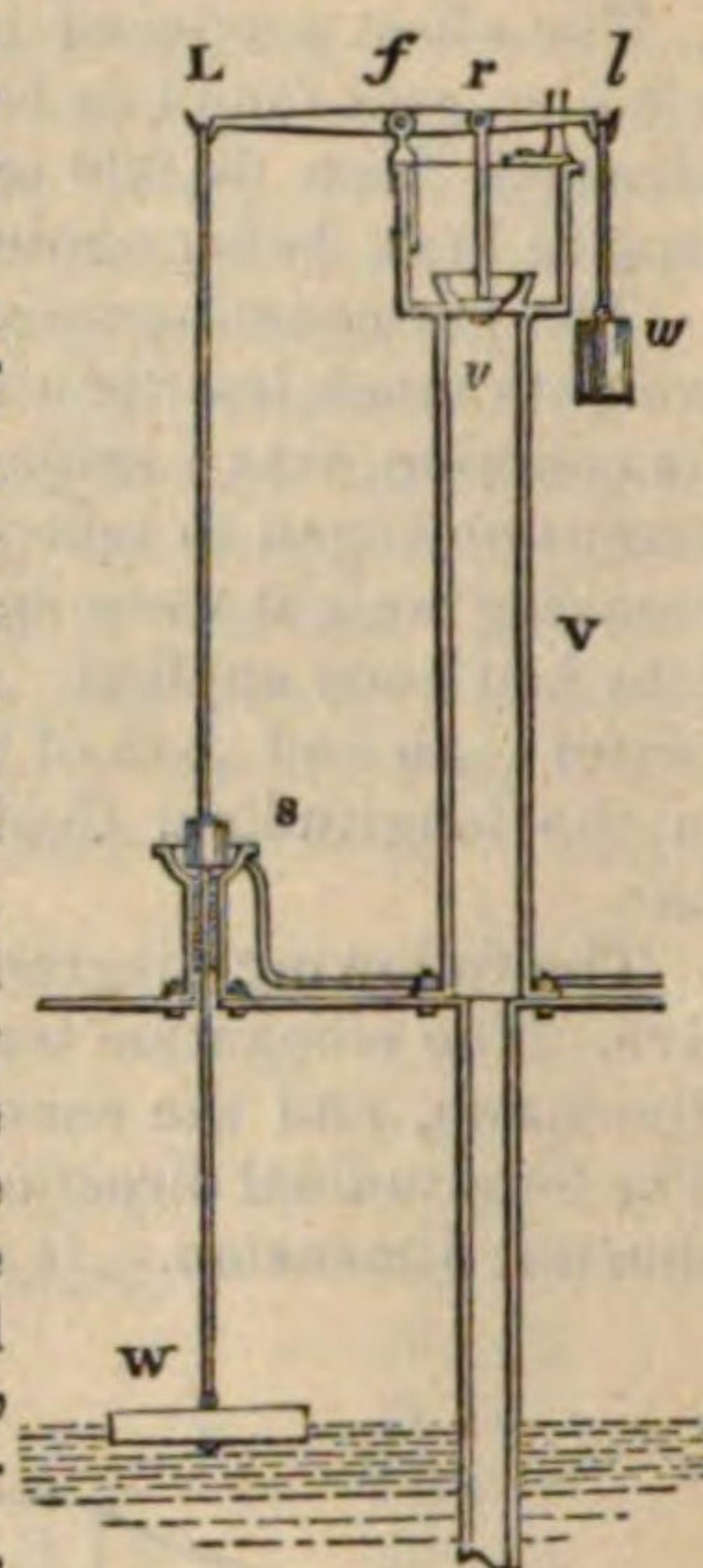
By these means, a careful attendant may always ascertain the state of the water in the boiler, with sufficient ease to enable him to regulate the supply of water thrown in, or the feed of the water to the boiler, so as to replace, with cold water, the deficiency occasioned by the continual conversion of the water into steam. But if by any cause the attention of the keeper should be directed from the examination of the state of the boiler, it will gradually become emptied, and will either be exploded or burned out, from being made red hot. Various contrivances have been attempted for the purpose of rendering boilers automatic; so that the very fact of the water becoming low in the boiler should of itself be the means of furnishing a fresh supply. The manner of accomplishing this is somewhat different in different circumstances; but the following methods are the most common and the best.

A self-regulating feeding apparatus may be adapted to the boiler of a low-pressure steam-engine, in the following simple way. The water that is to feed the boiler, is to be conducted into a reservoir *vr*, of some 18 inches diameter, having a long pipe to lead down from it to the bottom of the boiler. The top of this pipe is closed by a tapered plug which hangs by the rod *vr*, from a lever supported at *f*, and having two weights, one at either end, *W* and *w*. The larger weight *W*, of stone or cast

iron, rests on the surface of the water, in the boiler, and is counterpoised by a smaller weight *w* in such a manner, that a part of the weight *W* is sustained by the water; therefore, whenever the water in the boiler falls below the proper point, the weight *W* preponderates, the arm *L* of the lever is pulled down by the wire *WL*, which passes steam-tight through a stuffing box at *s*, the end of the lever *l* ascends, and the valve *v* being withdrawn, allows the water to descend through the open end of the pipe, and replenish the boiler; and after a time, when the supply has become sufficient to raise the water to its proper level, the weight *W*, and the end *L* of the lever, are raised, the opposite end *l* is depressed, and the valve *v* once more closed, until a further supply has become necessary, when it is given again in the same manner.

This self-acting valve is sufficiently efficient when the boiler is of low pressure, or when the reservoir is more than two feet two inches high above the surface of the water for every pound of pressure per square inch of the boiler. But it very often happens that the boiler is fed with cold water in a different manner: a force pump is attached to the steam-engine, by which each stroke of the engine sends back into the boiler a quantity of water equivalent to that which has been evaporated out of the boiler in forming the volume of steam which has given to the engine motion through that stroke by which the pump has been impelled. Now, if the size of the pump were accurately proportioned, so as to replace in the boiler at each stroke the precise quantity of water evaporated from it in the same interval of time by the engine, it is evident that no further provision for adjustment would be necessary. This quantity is exactly one cubic inch of water for each cubic foot of atmospheric steam given to the engine, or one cubic foot = six gallons per horse-power per hour. But the evaporation of the water to a steam-engine is not thus uniform, nor so easily determined. The variations of intensity in the fire cause steam more or less dense to pass over into the engine; the steam now raises the safety-valve and escapes into the air, and now falls below the standard; the boiler, now tight, and again allowing water and steam to leak through its joints, consumes a greater or a less quantity of steam; and thus, even with this automatic supply, there is required a regulating or governing power. A stopcock is attached to a pipe by which the feed-pump obtains its supply of water to force into the boiler, and so, by impeding or facilitating the passage of water into the boiler, the attendant may regulate the supply. We have said that this cock is attached to the pipe by which the pump obtains its supply of water, and not to the pipe by which the same pump forces its contents into the boiler it is about to supply; and we have done so for this reason, that it is dangerous to apply such a stopcock on the pipe between the pump and the boiler, because, if the force-pump become once filled with water, and be forced down by the engine when the stopcock is wholly or nearly closed, the pipe will be burst from the incompressibility of the water, unless its valves should be so leaky as to allow the water to pass back into the reservoir from which it has been withdrawn. As, however, it

Fig. 234.

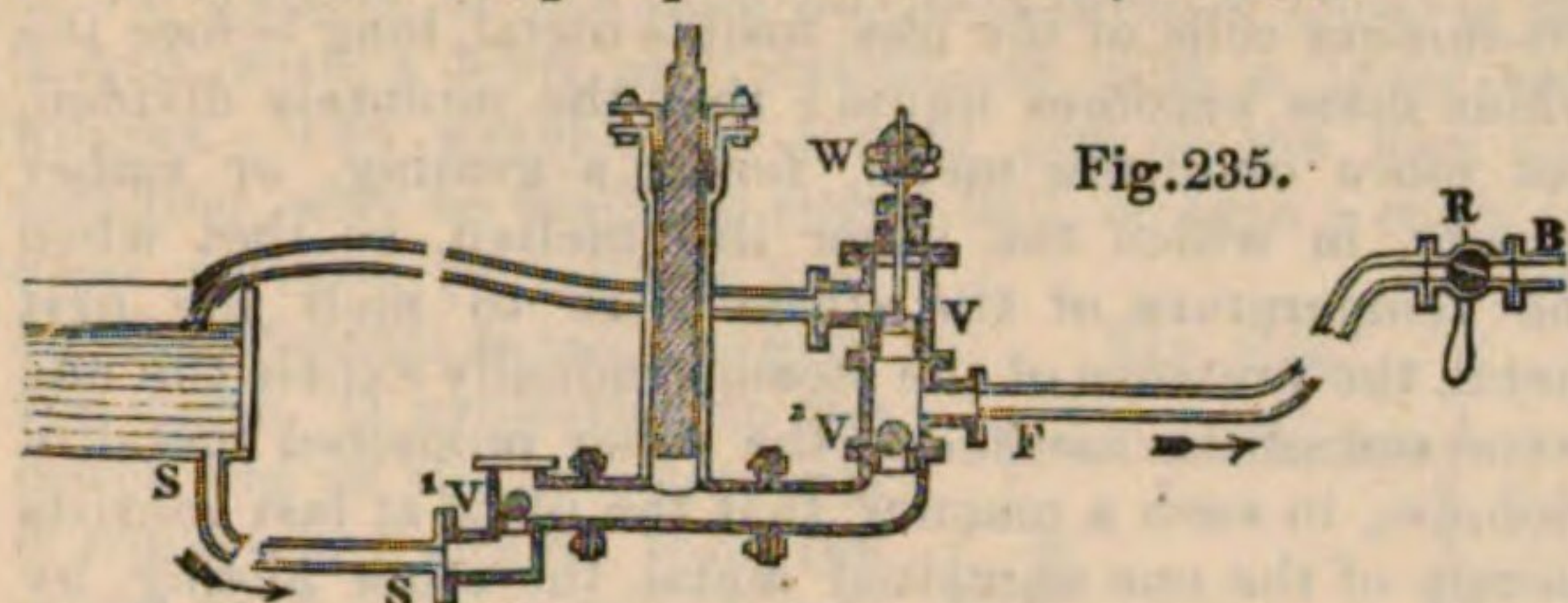


Steam-
Engine
Boilers.

Feeding
Apparatus.

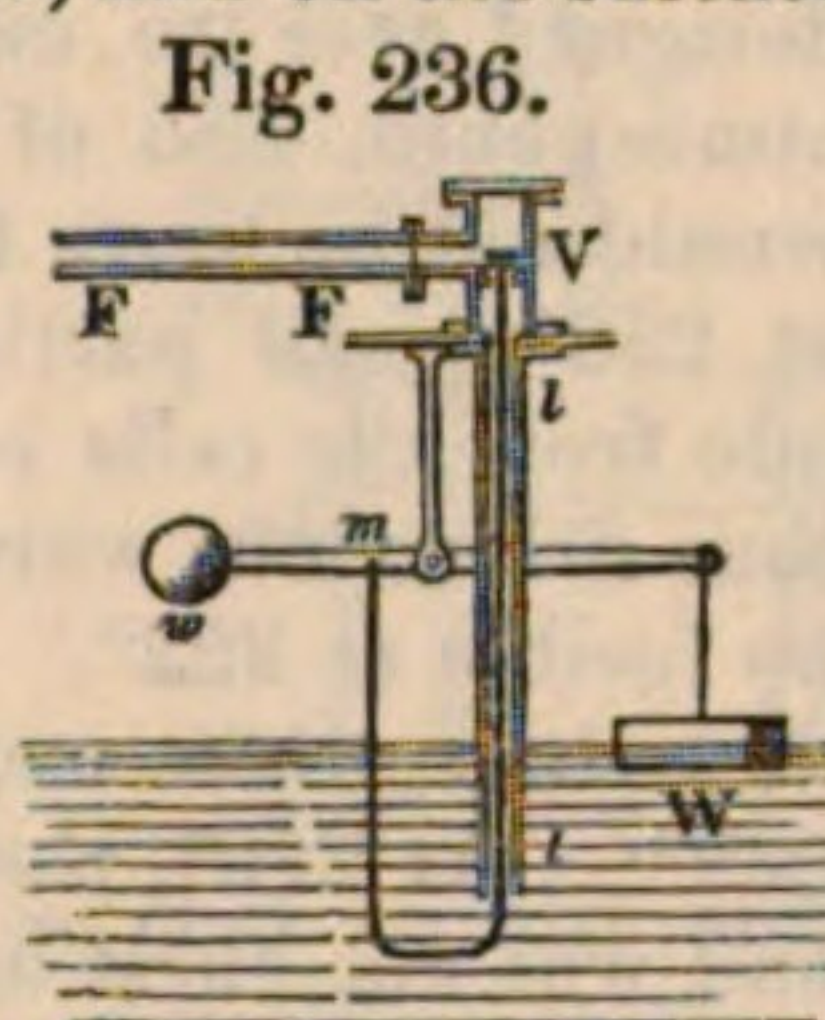
Steam-Engine Boilers.
Feed-Pump.

is sometimes desirable to have the regulating cock on the boiler feed-pipe, the following provision is made to render that method of regulation safe and efficient. Between the feed-pump and the boiler, there is



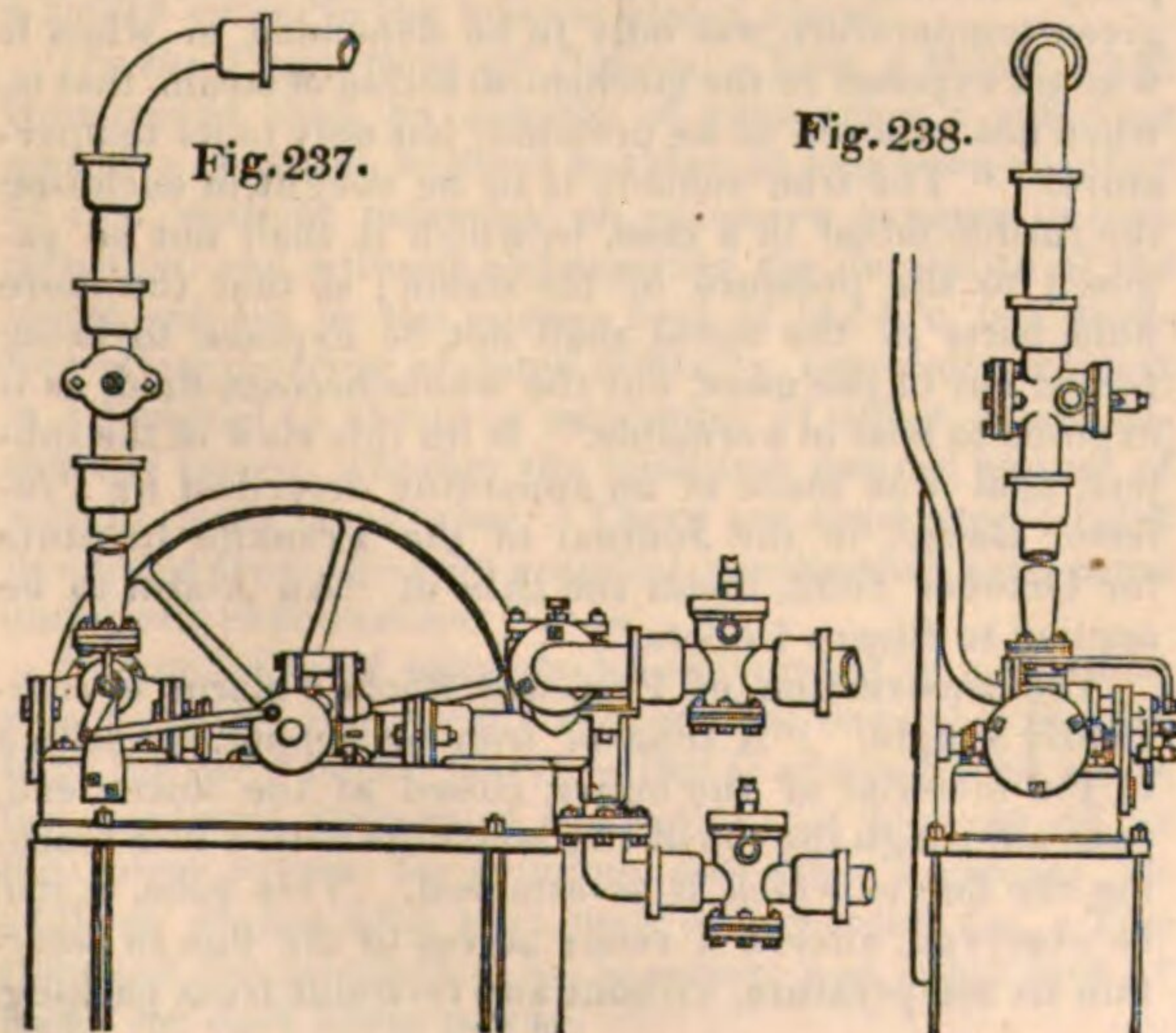
inserted, in connexion with the feed-pipe F, at any point V beyond the valve of the pump V² which prevents the return of the water into the pump, a loaded escape-valve V; its load W being so adjusted, that whenever the regulating stopcock R is turned so as to impede the passage of water towards the boiler B, the force of the feed-pump pushes the water up against the loaded valve V, and by it escapes through the return pipe r r r into the reservoir of supply H, again to be brought back into the pump when required for the future supply of the boiler.

Still, however, this apparatus depends in some measure on the adjustment of the regulator-valve R by an attendant; and contrivances have been invented to render this also automatic. In the boiler, and on the surface of the water, is placed a weight W, with a partial counterpoise w, so as to rest on the surface of the water. From the point m a small rod passes downwards and up again, through the feed-pipe L l to the point V, where a conical valve or plug V opens the communication with the feed-pipe F F and the water of the boiler when it is raised, and shuts it again when depressed. Now, when the water is abundant, the weight W floats high, and keeps down m and V; and when low, W descends, and raising m and V, admits the required supply into the boiler without any assistance.



Macdowall's Feeding Apparatus.

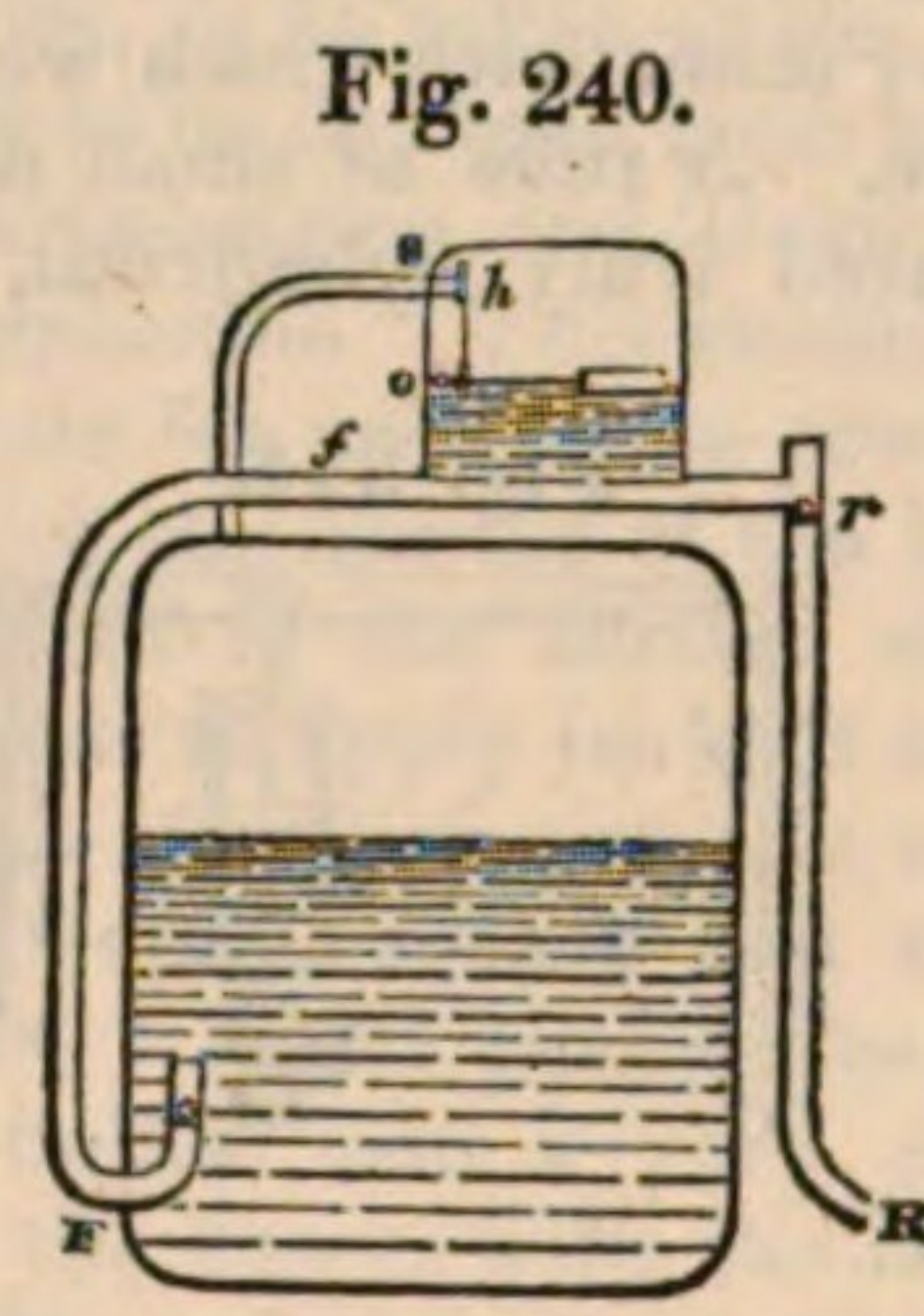
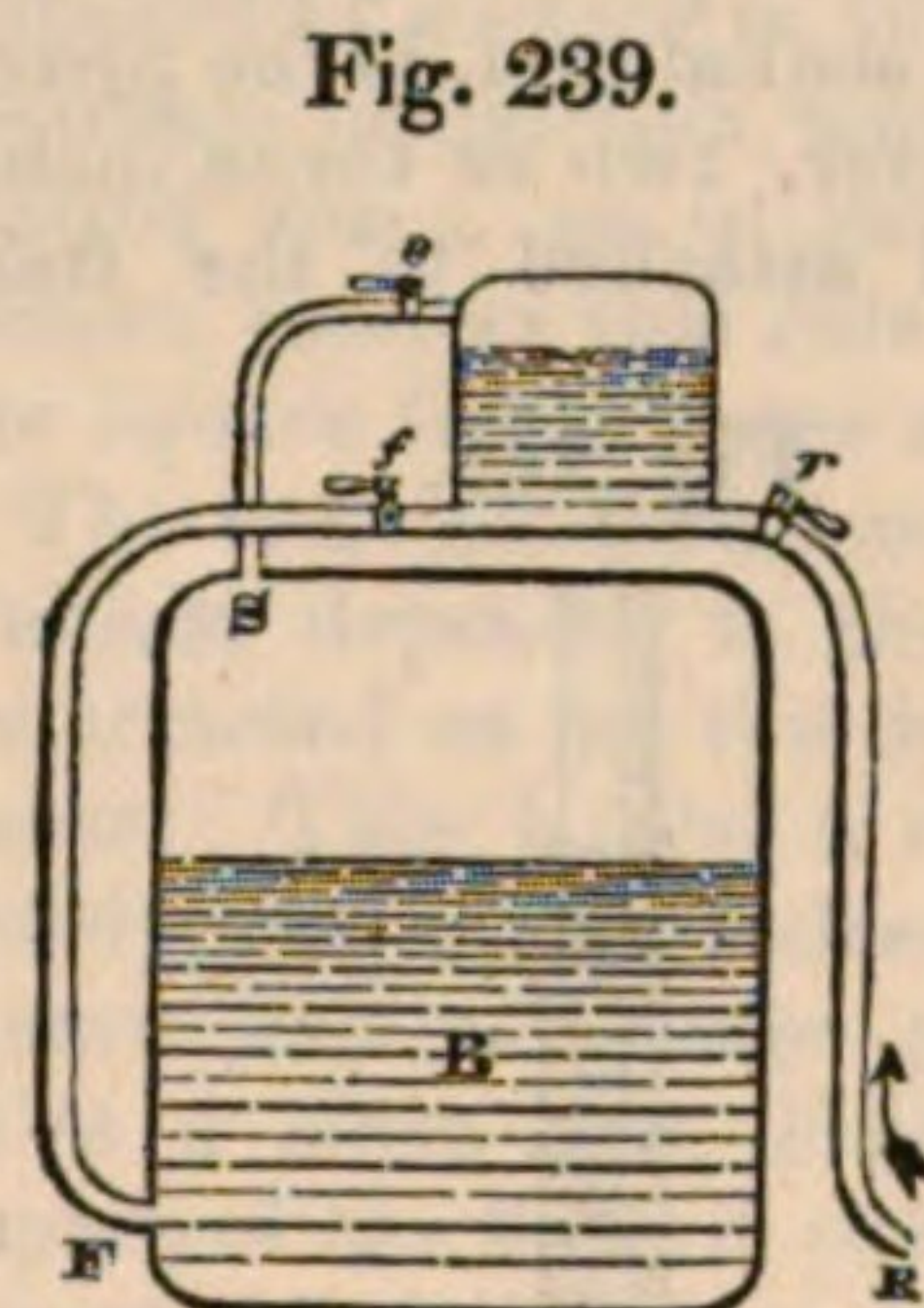
Where a high-pressure boiler is used for purposes in which a steam-engine is not employed, detached self-acting feeding apparatus must be employed. The following elegant and most effective apparatus has been invented by Mr Macdowall of Johnstown, and is now in extensive use in Scotland. We have seen it in an efficient working state, after being employed for many years, and it only costs about £20. It is nothing less than a small steam-engine, but it is applied in a most effective and simple way to the purpose designed.



VOL. XX.

A very simple feeding apparatus, on a similar principle, was adapted some years ago to the purpose of feeding a boiler without the assistance of a steam-engine. A close vessel or reservoir is placed above the level of the boiler, and is in communication with the water in the boiler through one pipe, and with the water to be supplied to the boiler through another; a third small pipe connects the steam-chest of the boiler with the top of the said reservoir. All these pipes being closed by moveable regulators or stopcocks, the attendant is first to open the steam communication, that the reservoir may be emptied of air and filled with steam, and the stopcock is then shut. In the next place, the communication with the cold water to be supplied is opened, and the reservoir on getting cool becomes vacuous, so that the pressure of the atmosphere fills it with cold water, and the communication is then cut off. Lastly, the third stopcock is opened, and the water in the reservoir having free communication with the water in the boiler, it is only necessary to open the steam-cock once more, and the water, being in equilibrium by the pressure of the steam, will run freely, by its own pressure, from its height above the boiler, into it; and the process of alternately filling and emptying the boiler may be repeated as often as required by turning the cocks in this succession. A simple process renders all these valves self-acting.

Steam-Engine Boilers.
Automatic Feeding Apparatus.



The reservoir, fig. 239, is a close vessel above the boiler B; R r is the cold-water pipe, by which the water is obtained, and is regulated by the stopcock r; F f is the feed-pipe for the boiler, regulated by the stopcock f; S s is the steam-pipe opened by the stopcock s. In the next figure, there is a balanced float on a pivot o, and a slit bar h connecting a small slide-valve s with a pin on the float-bar; r is a common ball valve, acting only upwards; and in F is a valve permitting the descent of the water in the pipe F f, and preventing its return. The latter is the self-acting form, of which the action once begun will continue indefinitely. A commanding valve being connected with the boiler-float, would render the play of this apparatus dependent on the requirements of the boiler itself. The reader who is acquainted with the steam-engine of Savary, will perceive at once that this reservoir, with its apparatus, is a mere Savary's steam-engine, applied to pump water into the steam boiler; and that this application of that engine is not liable to the objection urged against it in other circumstances, namely, that the water is heated as well as raised. In this instance, the communication of heat is attended with no loss.

Indices of pressure and safety apparatus, form an important series of appendages to a boiler. These are of four kinds; dynamometers, safety-valves, fusible plugs, and alarms.

The dynamometer, which is generally applied to measure the force of steam in a boiler, is a simple tube, bent upwards at the end, and formed sometimes of glass

Indices of Pressure.

Steam-
Engine
Boilers.
Bent-tube
Dynamo-
meters.

and often of iron. The two ends of this tube being curved up, so as to give it the form of the letter U, one of these extremities is applied to the boiler, and placed in communication with the steam; mercury is poured into the tube, so as to fill one-half of it, and the pressure of the steam upon one of the extremities of the column of mercury, forces the mercury to ascend in the other, and to indicate, on a divided scale, the amount of pressure, which is about one pound on the inch for each inch of height on the scale. It is necessary, in all these mercurial gauges, that the tube be of equal diameter throughout its length. If the tube be of iron instead of glass, it is necessary that a float of wood, or iron, or ivory, figure 241, resting on the top of it, should ascend above the tube, and indicate on a scale the place of the mercury. For high-pressure boilers a longer tube and scale are, of course, necessary; and a very convenient form for this purpose is given in figure 243. From a float resting on the fluid stretches a string carrying a counterpoise at the other end, and passing over a pulley raises or depresses the index of a valve on which the pounds of pressure are indicated by the inches of the scale.

The Pis-
ton-Gauge.

Another very convenient index of pressure, preferable to any other with which we are acquainted, is the piston-gauge. A tube of small diameter, two or three inches, is bored truly cylindrical, and attached to the steam

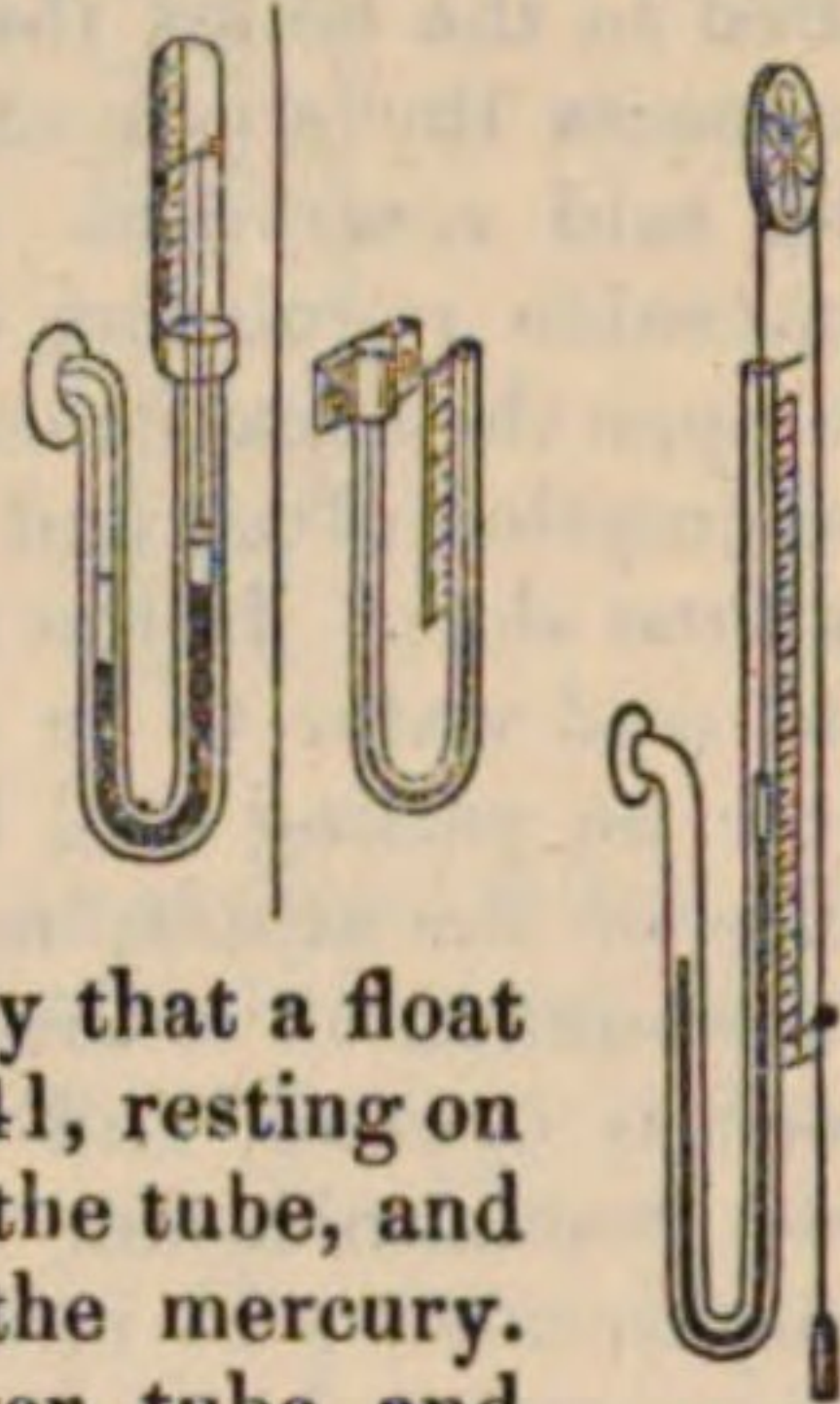


Fig. 244.

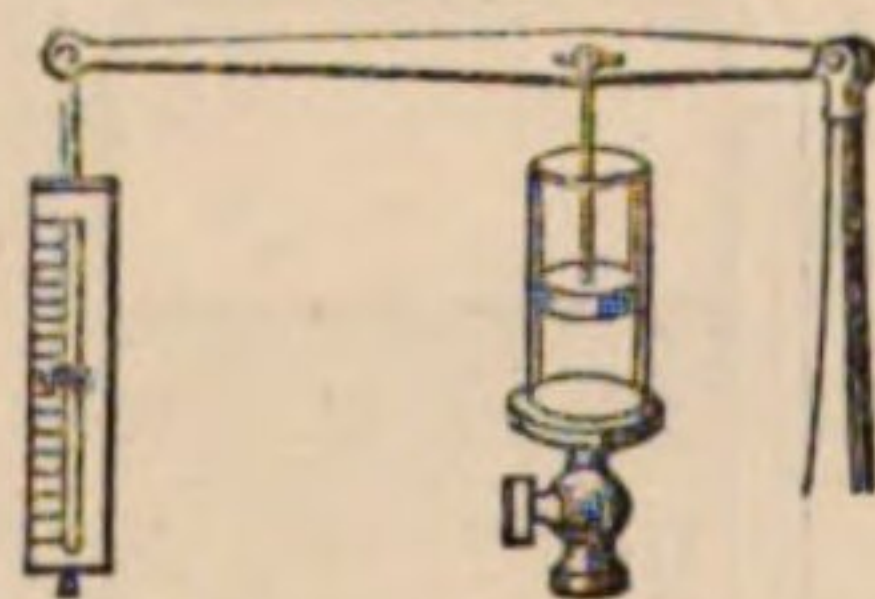


Fig. 245.



chest of the boiler, figure 244. This cylinder has a solid plug or piston truly turned, and ground exactly, but not loosely, into it. The pressure of the steam bearing up the piston on the lever, one end of which is attached to the spring indicator, gives the true indication of the pressure on the piston. The spring is also applied directly above the piston, as shown in the second figure; but this instrument is used on a smaller scale than the other. The ordinary safety-valves are described in another part of this article.

Safety Ap-
paratus.
Fusible
Plugs.

There is a species of safety boiler apparatus in which great faith has been placed by many mechanics and men of science. It has been proposed and enacted that boilers be furnished with fusible plugs, or that in parts of a boiler exposed to high temperature and pressure, there should be placed plugs, forming small parts of the boiler, which plugs being composed of metals easily melted, shall give way when by accident too great pressure and heat have been employed, and so, by a less evil, prevent the greater one of total disruption of the boiler. This method of creating a less evil to avoid a greater, has lately been shown to be fallacious, and ought to be abandoned. For the complete exposure of the inadequacy of the system of *rodelles fusibles*, we are indebted to the Committee of the Franklin Institute, already so often named with gratitude. The American experimenters found, that when alloys of tin, lead, and bismuth are applied to

steam boilers in the way recommended by the Commission des Rodelles Fusibles, the alloy does not melt in the manner of an homogeneous metal, as has been supposed; but that, in fact, the more fusible metal melts in the minute cells of the less fusible metal, long before the whole mass becomes liquid; that the minutely divided, but more obdurate metal, forms a grating, or rather sponge, in which the other lies melted, so that when the temperature of the steam rises to melt the first metal, the pressure of the steam gradually expels the one metal out of the meshes of the other unmelted metal in globules, in such a manner, that the plate at last consists merely of the one unmelted metal, the other having, by repeated heatings, completely exuded from it, and been replaced by such particles of debris as the water of a boiler in common use always supplies in abundance. Thus, a plate of two metals, originally designed to give way at 250°, may still deceive the unconscious attendant, and withhold its warning till it have reached a temperature of 500°, and contain a combination of caloric and water as dangerous as gunpowder, and greatly more treacherous.

The following experiment will illustrate the whole of this enquiry. A plate of alloyed metals, of which the melting point in the crucible was about 260°, was submitted to heat under pressure. Such a plate would be applied to a boiler, of which the temperature was not designed ever to exceed in the most extreme case one atmosphere, and of which the usual working pressure would not be more than 5 or 10 lbs. It was found that at 256° small particles of melted metal began to exude from the cells of the unmelted metal; the globules thus driven out were carefully examined, and found to be fusible at 222°. At 260°, a second portion exuded, and their dross were found to melt by themselves at 232°. At 270°, the remaining metal was still tenacious, and was not burst until the steam reached a temperature of nearly 300°, with an explosive force of three times that at which it should have given warning by fusion, and the escape of water and steam, from the small aperture it had filled. This last residual porous plate of metal was found not to melt until it reached the temperature of 345° instead of 260°. "These experiments the Committee (properly enough) deem conclusive, in regard to the use of fusible plates in the ordinary way; and they conceive that substituting fusible plugs of greater thickness, say half an inch, as has been directed by a recent ordinance in France, would not serve as a remedy to the defect thus exposed."

The true remedy for this evil was the next object of the enquiries of this excellent Committee. They properly inferred, that the fusion of an alloy of metals at a given temperature was only to be depended on when it was not exposed to the mechanical action of steam, that is, when not exposed to its pressure, but only to its temperature. "The true remedy is to be sought in enclosing the fusible metal in a case, in which it shall not be exposed to the pressure of the steam; so that the more fluid parts of the metal shall not be exposed to being forced out of the mass, but the whole become fluid, as if exposed to heat in a crucible." With this view of the subject, trial was made of an apparatus described by Professor Bache, in the Journal of the Franklin Institute for October 1832, under the title of "An Alarm to be applied to Steam Boilers."

The construction of Professor Bache's alarm is sufficiently simple. "A tube of iron or copper, according to the material of the boiler, closed at the lower end, passes through the top of the boiler, its closed end reaching the flue to which it is attached. This tube, it will be observed, affords a ready access to the flue to ascertain its temperature, without any restraint from packing."

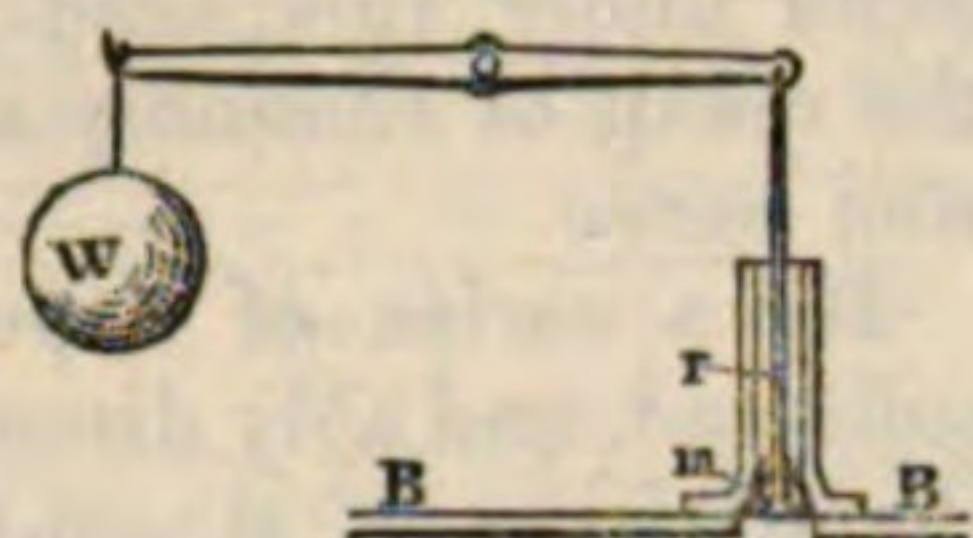
Steam-
Engine
Boilers.
Fusible
Plugs,
their in-
utility de-
monstrat-
ed.

Professor
Bache's
Alarm.

Steam-Engine Boilers.

A mass of fusible metal placed at the bottom of the tube will become fluid very nearly as soon as the flue takes the temperature of its fusion. To show when the metal at the bottom of the tube becomes fluid, a stone is attached with a cord and weight, or with a lever and weight. The weight and longer arm of the line, descending, may be made to ring a bell, or turn a cock, or open a valve, permitting just enough of steam to issue, to give the alarm. A projection on the lower end of the rod prevents it from being drawn from the metal until this latter is fused, and by widening the lower part of the tube the metal is kept from being drawn out by the rod. BB, fig. 246, is part of the boiler plate; *m* the fusible metal in a tube; *r* the rod to which it is, as it were, soldered, and when the metal melts, the weight *W* will descend and give the alarm, either by striking a bell, opening a steam whistle or trumpet, or raising a valve. This apparatus of Professor Bache's is a valuable addition to the mechanism of steam.

Fig. 246.



Professor Bache's Alarm.

Noisy Alarms.

The common alarms, the steam whistle, and the steam trumpet, may be made to give noisy indications of an excessive pressure of steam. A small box on the steam chest is to cover a lock-up safety-valve, loaded at the highest pressure the boiler should endure. On this box is to be placed a steam whistle or a steam trumpet, so that an alarming noise will be the consequence of any excessive pressure; for the steam issuing through the aperture of the instrument will give it voice with an intensity proportioned to the pressure.

Fig. 247.

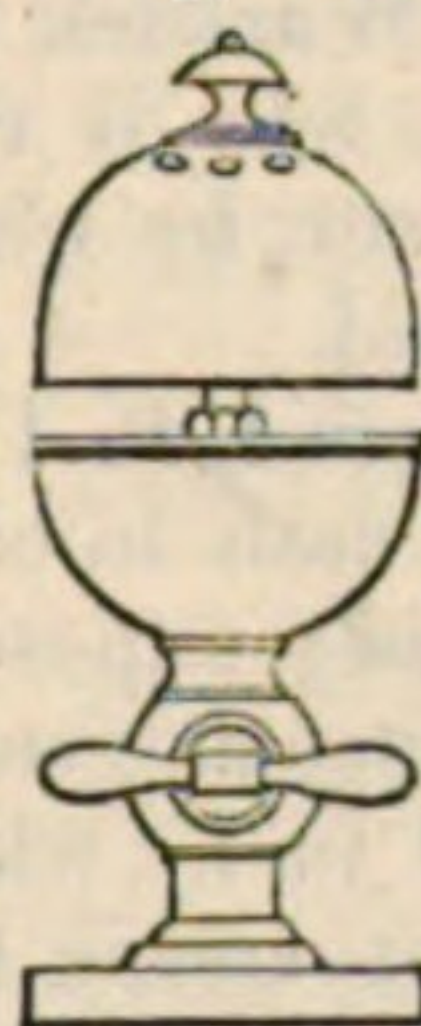
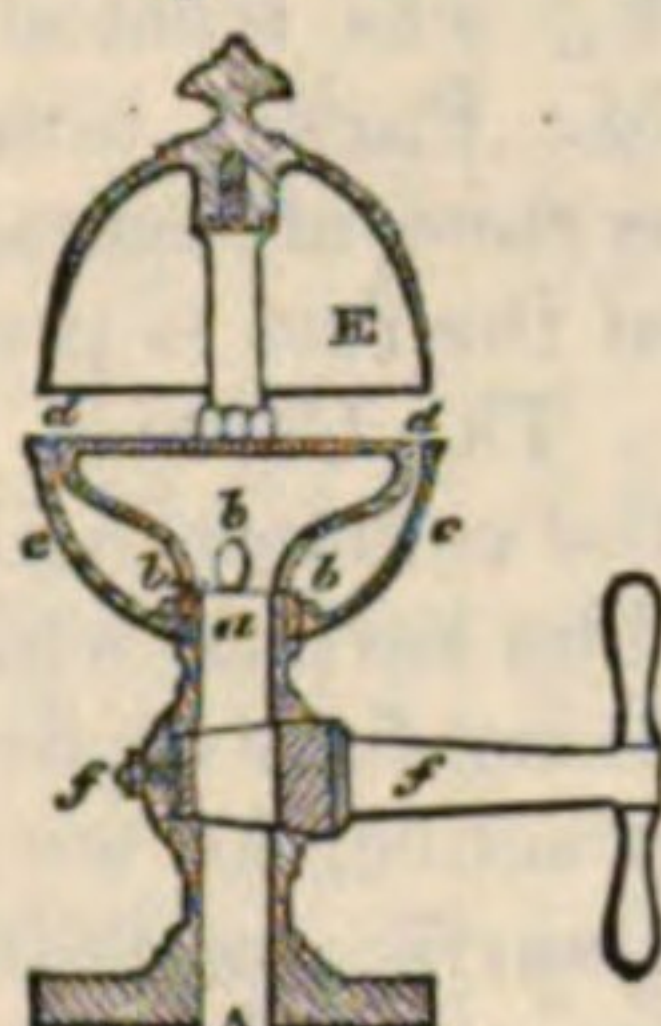


Fig. 248.



The steam whistle.

In figs. 247, 248, a steam whistle is represented. A *a* is a tube leading from the boiler; in it is a stopcock. On the top of the tube is a hollow piece *bb*, surrounded by a thin cup *cc*, and carrying, by a pillar fixed on its top, another inverted cup *E*. When the stopcock is opened, the steam enters the cup *cc* through holes in the foot of the hollow piece *bb*, and rushing out at the narrow orifice *dd*, between the cup *c* and hollow piece, strikes on the edge of the cup *E*, and produces an exceedingly loud and shrill sound. No stopcock is, of course, required when this alarm is placed on the box of a safety-valve, in the manner stated above.

Proportions of Boilers, &c.

On the Proportions of Boilers.—That a boiler when constructed shall be capable of generating a sufficient quantity of steam, without burning an excessive quantity of fuel, without incurring an excessive expense in construction, and without endangering the durability of the metal, subject to the intense heat of the fire, is a problem of engineering of some difficulty, especially when it is attempted to obtain a maximum of effect at a minimum of means, whether the minimum desired be that of weight, bulk, or expense. There are some simple rules deducible from the best practical results that have come under our examination.

Quantity of water required per H.P.

The quantity of water to be evaporated in a common steam-engine, is generally reckoned at one cubic foot an hour for each horse power. But if allowance be made for accidental leakage of the boiler, for blowing off at the safety-valves, for priming, and other accidents, an addition of one-fifth part may be provided for. The standard for calculating is, however, one cubic foot of water for each horse power.

The area of the grating in the furnace on which the fuel is laid, is an important element of efficiency in a steam-engine boiler. Here practice somewhat varies. The bars are generally about one inch wide on the top and the interstice from $\frac{1}{4}$ to $\frac{1}{2}$ an inch. These apertures supply oxygen to the fuel, and regulate the combustion, which is only perfect when the supply of air to the incandescent fuel is ample. It is found that a supply of air, such as will pass through each square foot of the area of the grate of the fire, is adequate to the effectual combustion of so much fuel as will, in a proper boiler, evaporate one cubic foot of water an hour, and supply one horse power in a steam-engine. Thus, a fire grate 6 feet long by 6 feet wide, containing $6 \times 6 = 36$ square feet, is found to give an ample supply of air for the combustion of as much fuel as will supply an engine of 36 horse power, evaporating 36 cubic feet of water an hour. But although this is a safe and excellent proportion for ordinary practice, yet it has been found, that with a quick draught a smaller amount of fire surface is adequate to the effect required. So low a proportion of fire grate as $\frac{2}{3}$ ds of a foot, and even $\frac{1}{2}$ of a square foot to each horse power, has been employed by eminent engineers, and has succeeded, while others recommend a much larger allowance even than one square foot. It is certain that the larger area of fire-grate is conducive to economy and durability. The standard of surface is, therefore, to be taken at the most desirable proportion, and only to be deviated from where limited space, as in locomotive-engine and steam-ship boilers, renders this rule inapplicable. This standard is one square foot of area of grate for each horse power.

Steam-Engine Boilers.

Area of the Fire Grating.

The next condition on which the success of the boiler problem depends, is the extent of the surface of the boiler acted on by the fire, so as to apply its heat to the water. This is also a subject on which practice varies widely; so widely indeed as from 8 square feet to 36 square feet per horse power. Eight square feet require a clean thin copper boiler, and a very direct impact of the hottest part of the flame, with the loss of a portion of the heat; but 36 square feet, on the contrary, imply the possession of profuse space, and a desire to economise to the very utmost the powers of the fuel. The standard of practical effect with the usual iron boilers, in ordinary circumstances, is fifteen square feet of heating surface for each horse power.

Extent of heating surface, per H.P.

Of this surface, about one-third is horizontal, and two-thirds are vertical surface; and of these, the horizontal surface is imagined to be twice as effective as the vertical surface. Arguing on this supposition, some have given it as a rule to calculate *each vertical foot as only half an effective foot* of heating surface, and so to make nine or ten square feet of effective heating surface the standard of boiler power. But this rule, though giving the same result as the former, proceeds on a supposition not yet established, and which does not always coincide with the fact. It will be easily seen that 5 feet of horizontal surface, added to 10 feet of vertical surface, making, according to the one mode of calculation, 15 feet of surface, divided in the proportion of two-thirds vertical and one-third horizontal surface, forms an exact equivalent to the other mode—of reckoning the 10 feet of vertical surface only equal to 5 effective feet of surface, and adding to the said 5 effective feet of surface the 5 feet of horizontal surface, making in all 10 feet called effective feet of heating surface.

The next essential consideration is the area of the chimney and flues. It has already been given as a standard, that the fire grate should have the area of one square foot for each horse power. Now, this area for the admission of air should be accompanied with a sufficient passage to carry off the gaseous products, and hot

Area of Chimney and Flues.

Steam-
Engine
Boilers.

air and flame resulting from combustion. From an examination of the best boilers, it appears to us decided that one-fifth of the area of the fire grate, gradually diminishing to a chimney, which shall have one-tenth of the area of the fire grate, is an excellent proportion. We therefore feel disposed to recommend it as a standard for steam-engine boilers: one-fifth, diminished at the chimney to one-tenth part of the area of fire grate.

The chimney should be of the same diameter throughout its interior; and if of 40 feet height and one-tenth part of the area of the fire grate, it will give an abundant draught. If the height of the chimney be greater than this, the area may be diminished as the square root of the height is increased.

Data for
fixing the
size of a
boiler.

The quantity of water to be contained in a boiler is a matter of some importance. If we consider bulk and weight as of no consequence, and if the boiler be in constant work, there cannot, perhaps, be too much water. On the contrary, if there be only a small quantity, many evils are encountered. In the first place, a large mass of water serves to regulate the production of steam from a boiler, much in the same way as a fly-wheel regulates the speed of an engine; whereas with a small charge of water, the unavoidable oscillations that happen in the supply of cold water or the additions to the fire, make sudden and injurious changes in the production of steam. In the next place, it is well known that steam is a very bad conductor of heat, and has a single capacity in its gaseous state for the acquisition of caloric. Hence it is found that if the production of steam be rapid, and the water present in a smaller proportion, the caloric is not carried off from the metal heated by the fire sufficiently fast, the boiler is overheated and rapidly deteriorates, while the production of steam is greatly retarded. For these reasons, it is necessary to have a large supply of water. Eight to thirteen cubic feet are very commonly allowed by practical men. As a standard, or perhaps as a minimum, we may assign for the quantity of water in the boiler, in its mean condition, ten cubic feet of water in the boiler for each horse power. In like manner, we will do well not to leave a smaller proportion of capacity in a boiler for containing steam than the quantity assigned for the water, being ten cubic feet of steam in the boiler for each horse power.

Economy of Fuel in Steam Boilers.—The ordinary consumption of coal by one of Mr Watt's engines is 10 lbs. of fuel for each horse power every hour. The work done by this fuel is equivalent to the power of raising 150 lbs. 220 feet high in a minute, or of raising 220 times 150, that is ($220 \times 150 = 33,000$) 33,000 lbs. one foot high, or any equal product of mass by height in every minute, by the combustion of 10 lbs. of coal, or 3,300 lbs. of weight raised one foot high every minute, which gives in every hour 198,000 lbs., raised one foot high by the combustion of one lb. of coal. This, however, by care and economy, is often exceeded by Mr Watt's engines; and the following are about the standards of work done at a given expenditure of fuel in ordinary engines, which is called the Duty of Steam Engines.

Duty of
engines.

The Duty performed by Ordinary Steam Engines is—
One horse power exerted by 10 lbs. of fuel an hour.
Quarter of a million of lbs. raised one foot high by one lb. of coal.

Twenty millions of lbs. raised one foot by each bushel of coals.

The constant aim of engineers is to increase the amount of this duty; in other words, to make a less quantity of fuel than 10 lbs. do the work of one horse, or to obtain a greater duty than a quarter of a million of lbs. from one lb. of fuel, or more than 20 millions of duty from a bushel or 84 lbs. of fuel. To such an extent

has this effort been successful, that one cubic foot of water has been converted into steam capable of exerting one horse power by the combustion of less than 5 lbs. of coal; and this steam has been so managed in the engine as to raise one million of lbs. one foot high by one lb. of coal, and in one case 125 millions of lbs. by a bushel of coals was the duty obtained in Cornwall. Of these improvements part is due to the economy of steam in the engine itself, and does not come under this head. That part, however, which is the result of economy in the boilers deserves our attention here.

By a series of experiments, carefully conducted or collected, and ably discussed, by Mr. Parkes of Warwick, the statistics of steam-engine boilers have been placed in an aspect sufficiently clear to enable us to deduce some general results of considerable economic importance. These experiments are contained in the table on the opposite page.

The observations contained in this table are made upon three great classes of boilers; the Cornish high-pressure boiler, I. to IV.; the waggon boiler and common low-pressure boiler, V. to XIV.; and the locomotive-engine boiler, XV. and XVI. The waggon boiler, V., was treated at Warwick in a peculiar manner by Mr Parkes himself, who is the advocate of a peculiar system of management, by which very slow combustion of the fuel is produced.

The Cornish boilers I. to IV. are distinguished from the common boilers, both in construction and treatment. The surface which they expose to the fire is enormous, being four or five times as great as the standard of usual practice, as we find in I., where 34 horse power has a surface of 2600 feet, and in II., where 48 horse power has a surface of 3170 feet exposed to the fire. This species of boiler is invariably cylindrical, and traversed longitudinally by cylindrical iron flues. It is also surrounded by external flues, except on the upper surface, which is placed under a roof, and enclosed to a considerable depth in sawdust, or other nonconducting matter. The circuit which the flame and hot gases perform, in contact with the flues, is about 150 feet long. The treatment of the Cornish boiler is as peculiar as its structure, for instead of a strong draught, a tall chimney, and an intense fire, the fuel is laid on in large masses, it is allowed to cake and to consume very slowly, while its products pass up the chimney after having paid a leisurely visit to the two or three thousand feet of absorbent heating surface that surround its long and circuitous passage towards the open air. Very perfect combustion is obtained by the thorough combination of the oxygen, and the ample time permitted for the communication of the heat thus developed. Durability in the materials used, economy in the fuel employed, and increase of useful effect, are obtained by the Cornish construction and usage, to an extent that excels every other mode of generating steam with which we are acquainted.

The economy of the Cornish boiler and its causes may be estimated by comparison with the standards we have already given of very ordinary practice.

CONDITIONS.	ORDINARY STANDARD.	CORNISH BOILER.
Area of fire grate in square feet	1	2
Area of heating surface in do.....	15	60 to 70
Circuit of heat	60 ft.	150 ft.
RESULTS.		
Fuel per horse power per hour	10 lbs.	5½ lbs.
Fuel consumed per hour per ft. of grate	10 lbs.	2½ lbs.
Water evaporated by each lb. of coal	6 lbs.	11½ lbs.

Steam-
Engine.
Boilers.

Experi-
ments of
Mr Parkes.

STEAM-ENGINE BOILERS.

685

Steam-
Engine
Boilers.
Statistical
Tables.

Steam-
Engine
Boilers.
Statistical
Tables.

EVAPORATION AND COMBUSTION OF STEAM BOILERS.

STATISTICAL TABLES

OF THE

PARTICULARS OF THE BOILERS.											PARTICULARS OF THE COMBUSTION.											PARTICULARS OF THE EVAPORATION FROM THE INITIAL TEMPERATURE OF THE WATER.											PARTICULARS OF THE EVAPORATION OF WATER AT THE TEMPERATURE OF 112°.											PARTICULARS OF THE PROPORTIONS OF HEATED SURFACE TO FUEL BURNED AND WATER EVAPORATED.										
No. of experiment.	Place of experiment.	Nature of coals used.	Form of the boilers.	No. of boilers in use.	Length.	Breadth.	Diameter.	Total area of heated surface.	Surface exposed to radiant heat.	Surface exposed to communicative heat.	Length of circuit made by the heat in one boiler.	Area of the grates.	Weight burnt per square foot of grate per hour.	Weight burnt per square foot of heated surface per hour.	Temperature of the water entering the boilers.	Pressure of the steam above the atmosphere.	Cubic feet evaporated per hour.	Pounds evaporated per 11b. of fuel.	Pounds of fuel evaporating one cubic foot of water.	Pounds of water evaporated by the products of combustion per square foot of grate per hour.	Pounds of water evaporated per square foot of heated surface per hour.	Pounds evaporated by 11b. of fuel.	Pounds of fuel evaporating one cubic foot of water.	Pounds of water evaporated by the products of combustion per square foot of grate per hour.	Pounds of water evaporated per square foot of heated surface per hour.	Square feet of heated surface to one square foot of grate.	Square feet of heated surface per lb. of fuel burnt per hour.	Square feet of heated surface per lb. of water evaporated per hour from its initial temperat.	Square feet of heated surface per lb. of water evaporated per hour from 212°.	Square feet of heated surface per cubic foot of water evaporated per hour from its initial temp.	Square feet of heated surface per cubic foot of water evaporated per hour from 212°.																							
I.	Cornwall. Huel Towan	*W. Cyl.	3	3	ft. 36 36 40	ft. ..	ft. in. 6 0	sq. ft. 2600	sq. ft. 114	sq. ft. 2486	ft. 152.	sq. ft. 72.0	lbs. 2.83	lbs. 0.078	deg. 93.8	lbs. 49.4	c. ft. 34.82	lbs. 10.88	lbs. 5.90	lbs. 29.94	lbs. 0.829	lbs. 0.977	lbs. 11.89	lbs. 5.25	lbs. 33.66	lbs. 0.932	sq. ft. 36.11	sq. ft. 12.75	sq. ft. 1.205	sq. ft. 1.072	sq. ft. 74.67	sq. ft. 67.04																						
II.	United Mines	W. Cyl.	3	3	ft. 36.66	ft. ..	6 4	3170	98	3072	158.	70.0	4.09	0.093	96.0	35.0	48.04	10.48	5.95	42.90	0.977	11.76	5.31	48.13	1.096	43.88	10.72	1.022	0.911	63.94	56.98																							
III.	Mean of exp. I. & II.	W. Cyl.	3	3	36.66	..	6 2	2885	106	2779	155.	71.0	3.46	0.085	94.9	42.2	41.43	10.53	5.92	36.42	0.903	11.82	5.28	40.89	1.014	39.99	11.73	1.113	0.991	69.30	62.01																							
IV.	East Crinnis Binner Downs	W. Cyl.	2	2	ft. 34 36 30	ft. ..	ft. in. 6 9 7 0 6 0	2500 1440	57 76	2443 1364	152.33 132.	37.5 48.0	7.00 4.62	0.104 0.154	..	..	..	..	..	..	..	..	..	..	..	..	66.66 30.00	9.52 .48	..	..	..	..																						
V.	Warwick	S. Wag.	3	3	ft. 15.0 12.5	ft. 6.0 5.0	..	455.0	107.0	338.0	50.66	70.5	4.00	0.019	93.0	2.5	41.38	9.17	6.81	36.68	5.684	10.32	6.05	41.28	6.396	6.45	1.61	0.1759	0.1563	10.99	9.77																							
VI.	Chithero	L. Wag.	1	1	20.0	5.5	..	320.0	23.62	256.38	91.0	17.6	11.53	0.634	44.0	5.0	18.55	5.71	10.94	61.90	3.695	6.73	9.27	77.69	4.973	18.18	1.57	0.275	0.234	17.25	14.63																							
VII.	Ditto	L. Wag.	1	1	20.0	5.5	..	320.0	35.43	284.56	91.0	20.25	8.02	0.507	44.0	5.0	21.62	8.32	7.51	65.75	4.224	6.79	9.27	78.55	4.970	15.80	1.97	0.236	0.201	14.80	12.57																							
VIII.	Preston	L. Wag.	1	1	13.5	8.0	..	297.0	46.85	250.15	70.0	27.75	9.27	0.931	76.0	4.0	33.17	7.49	8.33	74.74	6.984	8.56	7.28	85.44	8.000	10.70	1.07	0.143	0.124	9.00	7.82																							
IX.	Ditto	L. Wag.	1	1	13.5	8.0	..	297.0	46.85	250.15	70.0	27.75	9.27	0.867	80.0	4.0	35.00	8.49	7.36	78.82	7.300	9.67	6.46	89.77	8.388	10.70	1.15	0.135	0.119	8.48	7.45																							
X.	Albion Mills	L. Wag.	1	1	16.0	6.0	..	521.5	35.0	486.5	70.0	24.5	16.44	1.110	74.0	2.5	44.25	8.38	7.45	99.65	9.311	9.60	6.50	114.13	10.663	10.70	0.900	0.107	0.093	6.71	5.86																							
XI.	Ditto	N. Wag.	1	1	15.0	5.5	..	345.0	31.5	313.5	56.0	22.66	12.79	0.840	100.50	2.5	32.52	7.00	8.91	89.71	5.891	7.82	6.48	158.55	7.448	21.28	1.294	0.150	0.134	9.38	8.39																							
XII.	Ditto	N. Wag.	2	2	15.0	5.5	..	345.0	31.5	313.5	56.0	22.66	12.79	0.840	100.50	2.5	32.52	7.00	8.91	89.71	5.891	7.82	6.48	158.55	7.448	21.28	1.294	0.150	0.134	9.38	8.39																							
XIII.	Mean of exp. VI. & XIV.	L. Wag.	1	1	36.66	6.5	..	342.81	39.82	302.98	72.5	26.09	10.75	0.798	77.0	3.68	34.40	7.76	8.18	83.83	6.289	8.86	7.15	95.50	7.166	13.88	1.315	0.171	0.149	10.77	9.39																							
XIV.	Long Benton ..	N. Circ.	2	2	..	..	1, 12 1, 13 6	469.0	71.0	388.0	52.8	35.10	20.34	1.55	152.0	1.5	90.00	7.87	7.93	160.25	12.250	8.37	7.46	170.36	13.02	13.08	0.642	0.0816	0.0767	5.10	4.79																							
XV.	Manchester & Liverpool Railway	Loc. Loc.	1	1	7.0	..	..	334.56	41.47	293.11	7.0	7.03	79.33	1.66	60.0	50.0	55.48	6.21	10.05	493.27	10.360	7.31	8.66	573.55	12.04	47.59	0.581	0.096	0.080	6.02	5.03																							
XVI.	Killingworth...	Coal Cote	Loc.	1	10.0	..	..	124.06	22.56	101.5	..	12.90	45.49	4.73	60.0	..	41.92	4.46	14.00	203.10	21.118	5.17	12.07	225.50	24.48	9.61	0.211	0.047	0.040	2.95	2.55																							

* W. indicates Welsh; S. Staffordshire; N. Newcastle; L. Lancashire.

Steam-
Engine
Boilers.

The few selections from the valuable magazine of practical facts presented in this table, serve to show how much is to be gained even without the assistance of new inventions, by judicious construction and treatment of ascertained and practical kinds of boilers and ordinary fuel. A saving of 50 per cent over ordinary practice is gained in Cornwall by large fire grates, thick fires, slow combustion, internal flues, extensive fire surface, and external coverings. He who desires to improve the construction or management of his boilers, has only to fulfil the conditions that are now brought under his attention.

The common waggon boiler stands contrasted in all points with the Cornish boiler. Yet it is cheering to see how much advantage may be gained by judicious

construction of fire grate, and a proper system in managing the fire, as is shown in Mr Parkes's experiments on his boiler at Warwick. The only peculiarities of the Warwick treatment appear to have been a large fire grate, $1\frac{3}{4}$ square feet to the horse power, and slow combustion, the high result of 10 lbs. of water evaporated by each pound of fuel, and the economical result of only 6 lbs. of fuel to each H.P. per hour, appear as the reward of this treatment.

The locomotive-engine boiler is in every point contrasted with the Cornish boiler. To pursue this part of the investigation more minutely than its exhibition in the table, would not coincide with the objects of this section.

(C. A.)

Steam
Engine
Boilers.

STEAM NAVIGATION.

Steam Na-
vigation.

THE application of steam-power to navigation is one of the most wonderful triumphs of human ingenuity.¹ By this power vessels of gigantic size are impelled across the trackless ocean; and, in spite of its storms and resisting tides, establish a chain of communication between the shores of the remotest regions, as safe and as certain as if connecting the cities of a continent. Thirty years have scarcely yet elapsed since the first steam-ship of traffic was launched on the Hudson, and now there is hardly a navigable river or an inland lake whose waters are not agitated by the steam-boat paddle, and its atmosphere darkened by her smoke; while even the ocean itself is crossed in almost every direction by lines of steam-ships of immense size, and of beautiful construction. Many individuals have claimed the merit of inventing an art so pregnant with interest to mankind; and almost every civilized country contends for the honour of its birthplace. If the mere suggestion of the application of steam-power to the purposes of navigation entitle an individual to the credit of having invented the art, there are, doubtless, many who may be regarded as its inventors; for this suggestion was repeatedly made almost as early as the invention of the steam-pump, although from the nature of steam machinery, then and for long after, no advantage could be derived from it. To show how the ingenious of that time were led to propose steam as a motive power in navigation, we shall give a brief account of the contrivances which had been devised for the propulsion of vessels.

The substitution of other apparatus than oars, and of other power than human labour, to impel vessels in a calm or against the wind, is of unknown antiquity. The Egyptians are said to have used, in their boats, wheels like the paddle-wheels of the present day, but moved by oxen working in a gin on the deck of the vessel. Valturius, in his treatise *De Re Militari*, gives an account of paddle-wheel boats used by the Romans as transports, the paddle-wheels being driven by men or by horses; and we have, from many sources, abundant evidence of the existence of similar boats elsewhere. In a book published in London in 1578, called *Inventions and Devices*, by William Bourne, we find the following passage: "And farthermore, you may make a boat to go without oars or sail, by the placing of certain

wheels on the outside of the boat, and so turning the wheels by some provision, and so the wheels shall make the boat goe." Thus we see that the means of making the boat go by paddle-wheels was already discovered, and the "some provision," by which these paddle-wheels were to be moved, was the desideratum. Horses, oxen, and human power had already been used for this purpose; and the first indication of some different power occurs in the Marquis of Worcester's *Century of Inventions*, published in 1663. The marquis, describing his *quintessence of motion*, says, "By this I can make a vessel of as great burthen as the river can bear to go against the stream, which, the more rapid it is the faster it shall advance, and the moveable part that works it may be, by one man, still guided to take the best advantage of the stream, and yet to steer the boat to any point. And this engine is applicable to any vessel or boat whatsoever, without being therefore made on purpose, and worketh these effects—it roweth, it draweth, it driveth, (if need be,) to pass London Bridge against the stream at low water; and, a boat laying at anchor, the engine may be used for loading or unloading." What the marquis's quintessence of motion was, or how applied to the moving of the vessel, we have not now the means of discovering; but, in his proposed applications of it, he has more than anticipated all that has yet been done; for we do not yet employ our steam-engines for loading or unloading. Savary, the inventor of the next steam-engine, proposed to apply his engine to impel boats. The only way, however, in which a rotatory motion could be derived from his engine was, by it to raise water into an elevated cistern, whence it could fall upon the floats of a water-wheel. This clumsy machine was not well adapted for a boat; and we hear nothing of its application. About the year 1688, the ingenious Dr Papin, who had been engaged with the project of an atmospheric vacuum-engine for moving machinery, proposed to form a vacuum in his cylinder with gunpowder, as had been proposed by Hautefeuille ten years before, and by Huyghens in 1680; but this scheme being found impracticable, he proposed, about two years afterwards, "to turn a small surface of water into vapour, by fire applied to the bottom of the cylinder which contains it, which vapour forces up the plug or piston in the cylinder to a considerable height, and which, as the vapour condenses, descends again by air pressure, and is applied to raise water out of the mine." Besides raising water from mines, he proposed also

Steam Na-
vigation.

¹ For these historical notices, ending in p. 693, we are not indebted to the same contributor who wrote the rest of the article.

Steam-Na-
vigation.

by a motion derived from the piston-rod of his engine, to impel the paddles of a boat. Here, with the discovery of the high-pressure engine within his reach, Papin relinquished his experiments; and Newcomen, adopting his cylinder and piston, and Savary's mode of condensation, a few years afterwards completed the atmospheric engine. The difficulty of converting the reciprocating motion of the atmospheric engine into a rotatory motion was the great bar to the use of it in any other way than for pumping water. Yet not a few speculators are to be found at this time inventing other means of propelling vessels than by paddle-wheels, so as to take advantage of the single reciprocating action of the engine. In 1730, Dr John Allen proposed to give motion to vessels by forcibly ejecting a stream of water or current of air from their stern; a scheme which, since his time, has been again and again invented, patented, and abandoned. Seven years after his proposal, Jonathan Hulls published an account of a steam-boat invented by him. In this boat, he had two paddle-wheels suspended in a frame projecting from its stern. In the body of the boat were two atmospheric engine cylinders with their pistons: to each piston one end of a rope was fastened; the rope was then carried round a pulley on the corresponding paddle-wheel, and one end was allowed to hang free, with a weight attached to it. When one of the pistons was pressed down in its cylinder by the weight of the atmosphere it pulled its rope, and, consequently, moved round the paddle-wheel in a degree due to the length of the stroke and the diameter of the pulley. While the piston was ascending in the cylinder, on the admission of the steam, the counterbalance weight, at the outer end of the rope, dragged round the pulley in the contrary direction; but the pulley being attached to the paddle-wheel by a ratchet-wheel, the latter remained stationary during the retrograde motion of the former. There being two cylinders and two paddle-wheels in the boat, it was so ordered that one should be in motion while the other remained stationary, and that thus the boat's motion should be continuous. However ingenious this plan of a steam-boat may be, we find no evidence that it was ever reduced to practice; but in a tract which Hulls published in 1737, he meets, and combats in a most masterly manner, every objection which he conceives might be urged against his project.*

In 1757, the celebrated Daniel Bernoulli, in an essay which obtained a prize from the Academy of Sciences, after demonstrating the effect of many mechanical contrivances which might be substituted for oars in moving vessels, suggests paddle-wheels moved by steam-power or the force of gunpowder. Another of the essayists, Gautier, a canon of Nancy, in suggesting the same mechanism and the same power, shows very great fertility of invention, and skilful application of mechanical resources in the adaptation of the different parts of the machinery.

In 1759, Mr J. A. Genevois, a minister of Berne, invented a species of propellers, which, like a duck foot, would expand, and present a large surface to the water when moved against it, but would fold up into small compass when moved in an opposite direction. It is scarcely necessary to say, that these duck feet oars failed; but it is a melancholy fact, that similar apparatus has been frequently re-invented since the days of the

pastor of Berne, and with the same degree of practical success.

Steam-Na-
vigation.

The Comte d'Auxiron, in 1774, under the auspices of a company formed for the purpose, made some experiments with steam-boats on the Seine. These unfortunately failed; but M. J. C. Perier, who had been present, repeated them with improved machinery, a year or two later. His success was so indifferent as to offer no inducement to him to continue his experiments. It is unnecessary to swell the present work with examples such as these; and we shall therefore at once proceed to the time of Watt, whose labours gave to the steam-engine its power of almost universal applicability, and eminently fitted it for the moving of paddle-wheels.

Leaving undescribed the experiments of the Marquis de Jouffroy on the Seine in 1782, and the attempts of Rumsey, of Fitch, and of Evans in America, between the years 1775 and 1787, which were attended with no beneficial effect, we proceed to notice the first attempts which were perfectly successful, and to which we more immediately owe the benefits of steam navigation. These were made in 1787, by a Scottish gentleman, Patrick Miller, Esq. of Dalswinton in Dumfries-shire, who, in that year, published an account of some experiments which he had made on the best mode of impelling single, double, and triple vessels, by the power of men and of horses applied to paddle-wheels. In this publication, Mr Miller states, "I have reason to believe that the power of the *steam-engine* may be applied to work the wheels, so as to give them quicker motion, and consequently to increase that of the ship. In the course of this summer I intend to make the experiment." He owed the suggestion of the steam-engine to a young man, Mr James Taylor, who resided in his family as tutor, and who had assisted him in his experiments; but neither Mr Miller nor Mr Taylor could devise a way of applying the engine to the boat. In this dilemma, Taylor suggested that they should have recourse to the aid of an old school-fellow of his, Mr William Symington, an engineer, at that time assiduously employed in endeavouring to adapt the steam-engine to wheel carriages. Mr Taylor seems to have sent an account of their project to Mr Symington, as we find the latter thus writing to the former, on the 20th August 1787: "I must make some remarks on your summer's inventions, which, if once made to perform what their author gives them out for, will undoubtedly be one of the greatest wonders hitherto presented to the world, besides its being of considerable emolument to the projector. Great success to you, although overturning my schemes." In the winter of the same year, Mr Miller was introduced to Mr Symington in Edinburgh, and saw the model of his locomotive carriage. Convinced of the perfect applicability of a similar engine to drive the paddle-wheels of a boat, Mr Miller gave orders for the construction of an engine on the same plan, under the direction of Symington and Taylor. The engine was accordingly made in Edinburgh, and sent to Dalswinton, and by them put together in October 1788. The engine, in a strong oak frame, was placed on one side of a twin or double pleasure boat on Dalswinton lake. The boiler was placed on the opposite side, and the paddle-wheels in the middle. In the middle of October, the machine was first put in motion; and the ingenious inventors had the gratification of witnessing the perfect success of the first steam-boat. Although the cylinders of the engine were but four inches in diameter, yet the boat attained a speed of five miles an hour. Mr Miller, anxious to try the experiment on a larger scale, commissioned Mr Symington to purchase a *gabert*, or large boat, at the Forth and Clyde Canal, and to get suitable engines

* A Description and Draught of a new invented Machine for Carrying Vessels or Ships out of, or into, any Harbour, Port, or River against Wind and Tide, or in a Calm: for which his Majesty has granted Letters Patent, for the sole benefit of the author, for the space of fourteen years. By Jonathan Hulls. London, 1737, 12mo.

Steam-Na-
vigation.

constructed at Carron. Every thing being completed, a trial took place on a level reach of the Canal, of about four miles in length, at Lock Sixteen. The trial was made in presence of many spectators, who were however disappointed in their expectations, owing to the breaking of the paddle-wheels. Stronger wheels were obtained, and another trial took place on the 26th December 1789, and the vessel moved at the rate of about seven miles an hour. Next day and afterwards the experiment was repeated with equal success; and the following account of it was transmitted by Lord Cullen to several of the Edinburgh newspapers:—"It is with great pleasure I inform you that the experiment which some time ago was made upon the great canal here by Mr Miller of Dalswinton, for ascertaining the powers of the steam-engine when applied to sailing, has lately been repeated with great success. Although these experiments have been conducted under a variety of disadvantages, and with a vessel built formerly for a different purpose, yet the velocity acquired was no less than from six and a half to seven miles an hour. This sufficiently shows that, with vessels properly constructed, a velocity of eight, nine, or even ten miles an hour may be easily accomplished, and the advantages of so great a velocity in rivers, straits, &c., and in cases of emergency, will be sufficiently evident, as there can be few winds, tides, or currents which can easily impede or resist it; and it must be evident that, even with slower motion, the utmost advantage must result to inland navigation." It is much to be regretted that Mr Miller, having made so successful an experiment, carried his attempts no further. The boat was dismantled and laid up at Carron; and this ingenious and public-spirited gentleman directed his attention to other objects. His pursuits had a greater tendency to improve the condition of his country, than to enrich his own family.

In 1793, Rumsey, who, as we have already stated, had been unsuccessful in his experiments in America, got some American residents in London to defray the expenses of another experiment there. He, however, died before his boat was finished; and when it was got afloat by those engaged with him, it attained a speed of four miles an hour against wind and tide. The propulsion of this boat was effected, on the principle of Dr John Allen's, by ejecting a stream of water at the stern.

In 1795, Earl Stanhope revived the pastor of Berne's duck feet oars; but he could not cause his vessel to move at a higher rate than three miles an hour.

In the year 1801, Thomas Lord Dundas employed Mr Symington to make a tug-boat for dragging vessels on the canal. With this view, a series of experiments were made between 1801 and 1802, at a cost of £3000. In March 1802, Lord Dundas, Mr Speirs of Elderslie, and several other gentlemen, being on board of the newly-constructed tug-boat, which was named the Charlotte Dundas, it "took in drag," says Mr Symington, "two loaded vessels, each upwards of 70 tons burden, and with great ease carried them through the long reach of the Forth and Clyde Canal to Port Dundas, a distance of $19\frac{1}{2}$ miles in six hours, although the whole time it blew a very strong breeze right ahead."

In consequence of an impression in the minds of some of the canal proprietors, that the paddle-wheels of the boat injured the banks of the canal, the project of the steam-tug was with great reluctance abandoned, and the boat was laid up in a creek of the canal, where it remained for many years exposed to public view. A year after this most successful experiment, Mr Fulton, an American, made a similar experiment on the Seine at Paris, under the auspices of the American chancellor, Mr Livingstone. Owing to a miscalculation of the strength of the boat, it had no sooner received the weight

of the engine than it broke through the middle, and went to the bottom. Not disheartened, Fulton set about building a new vessel; and in August 1803 he launched it with its machinery. This vessel was 66 feet long and 8 feet wide; but moved so slowly, that we may describe the experiment as a failure. He afterwards came to Scotland, and saw Mr Symington's vessel. Of this visit, a memorial of Mr Symington's, which we have before quoted, gives the following account:—"When engaged in these last experiments, I was called upon by Mr Fulton, who very politely made himself known, and candidly told me that he was lately from North America, and intended to return thither in a few months, but having heard of our steam-boat operations, could not think of leaving this country without first waiting upon me, in expectation of seeing the boat, and procuring such information regarding it as I might be pleased to communicate; he at the same time mentioned, however advantageous such invention might be to Great Britain, it would certainly become more so in North America, on account of the many extensive navigable rivers in that country; and as timber of the first quality, both for building the vessels, and also for fuel for the engine, could be purchased there at a small expense, he was decidedly of opinion it could hardly fail, in a few years, to become very beneficial to trade in that part of the world; and that his carrying the plan to North America could not turn out otherwise than to my advantage; as, if I inclined it, both the making and superintendence of such vessels would naturally fall upon me, provided my engagements with steam-boats at home did not occupy so much of my time as to prevent me from paying any attention to those which might afterwards be constructed abroad. Mr Fulton having thus spoken, in compliance with his most earnest request I caused the engine-fire to be lighted up, and in a short time thereafter put the steam-boat in motion, and carried him from Lock No. 16, where the boat then lay, four miles west the canal, and returned to the place of starting, in one hour and twenty minutes, to the great astonishment of Mr Fulton, and several gentlemen who at our outset chanced to come on board. During the above trip, Mr Fulton asked if I had any objections to his taking notes regarding the steam-boat; to which question I said, none, as I considered the more publicity that was given to any discovery intended for general good, so much the better; and having the privilege secured by letters patent, I was not afraid of his making any encroachment upon my right in the British dominions, though in the United States I was well aware I had no power of control. In consequence, he pulled out a memorandum-book, and, after putting several pointed questions respecting the general construction and effect of the machine, which I answered in a most explicit manner, he jotted down particularly every thing then described, with his own remarks upon the boat, while moving with him on board along the canal; but he seems to have been altogether forgetful of this, as, notwithstanding his fair promises, I never heard any thing more of him, till reading in a newspaper an account of his death.

"From the above incontrovertible facts, which can be corroborated by a number of persons of respectability living at this day, it is very evident that commerce is not indebted to North America for the invention of steam-packets, it being hereby established beyond the possibility of doubt, to be truly British, both in the idea and practice; and that Mr Fulton's steam-vessel did not make its first appearance in the Hudson river earlier than 1806 or 1807, four years at least posterior to his having been on board the Charlotte Dundas steam-boat, and minutely examined it, when at work on the Forth and Clyde Canal,

Steam-Na-
vigation.

Steam Na- and eighteen years later than the date of the first experi-
vigation. ments made by me upon steam-boats, on the lake at
Dalswinton, Dumfries-shire, in Great Britain."

Fulton, having obtained what information he could, ordered, under an assumed name, it is said, a steam-engine from Bolton and Watt. He shortly afterwards returned to America, and in conjunction with Mr Livingstone obtained a patent, securing to them the prospective advantages of steam navigation in America, by what they rather insincerely termed *their* invention of steam-boats. In 1806 Bolton and Watt's engine arrived, and in 1807 the first steam-vessel in America was launched on the Hudson river. It was called the *Clermont*, which was the name of Livingstone's residence. In spite of the advantages which it possessed over the Scottish vessels, in having better engines, and in its projectors having the benefit of Symington's experiments, it was a comparative failure, attaining at the utmost a speed of only *five* miles an hour. The boat had not been long under weigh, on its first trip, when Fulton ordered the engine to be stopped. Having observed that the paddle-wheel floats were too deeply immersed in the water, he shifted them nearer to the centre of the paddle, so that they did not enter so deeply into the water; and this alteration had the effect of increasing the speed of the vessel.

Shortly after this first experiment, it was announced that the *Clermont* would sail from New York to Albany; and of this first voyage the following account was sent to the Editor of the *American Citizen* newspaper, by Fulton himself:—

"Sir,—I arrived this afternoon, at four o'clock, in the steam-boat from Albany. As the success of my experiment gives me great hopes that such boats may be rendered of great importance to my country—to prevent erroneous opinions, and to give some satisfaction to the friends of useful improvements, you will have the goodness to publish the following statement of facts. I left New York on Monday at one o'clock, and arrived at *Clermont*, the seat of Chancellor Livingstone, at one o'clock: time, 24 hours; distance, 110 miles. On Wednesday I left the chancellor's at nine in the morning, and arrived at Albany at five in the afternoon: distance, 40 miles; time, 8 hours. The sum is 150 miles in 32 hours, equal to nearly 5 miles an hour, &c.—ROBERT FULTON."

During the same season, the boat made many voyages between New York and Albany, and in these she met with not a few accidents, arising chiefly from the defective construction of her paddle-wheels, which were of cast-iron, and had no support beyond the vessel. She was likewise injured by the sailing vessels, whose owners, dreading the intruder, ran them against her. The *Clermont* was at length laid up during the winter; and being enlarged and strengthened, she was again, in the spring of 1808, employed as a passage-boat between the same stations, and continued during the summer crowded with passengers. The success of their first vessel induced Messrs Livingstone and Fulton to build other two vessels, the *Car of Neptune*, of 300 tons, and the *Paragon*, of 350 tons.

Thus it was that steam navigation in America originated; and the enthusiastic and speculative Fulton enjoys the honour of having first shown to the world its commercial value. It is now proper time to mention that Fulton had been aided in his experiments on steam navigation by Mr Henry Bell, by whom the first steam passage vessel in Britain was constructed. The nature of this connexion will be better seen from Mr Bell's own account of it, which was addressed to the Editor of the *Caledonian Mercury* in 1816.

"Sir,—I observed in your paper lately a paragraph respecting steam-boats, in which the Americans claim the right to the discovery which is become of so much

VOL. XX.

utility to the public. On this account I propose to give you a full statement of what I conceive to be the truth. Mr Miller of Dalswinton first wrote upon the method of moving or impelling vessels or rafts through water by paddles, wrought by a capstan, or by the wind, in the manner of a wind-mill, which idea he afterwards gave to all the different courts in Europe. It will be recollected by most people in this country, that the French proposed to erect rafts for conveying troops to invade this country, by means of Mr Miller's wind-mill or capstan plan; for, it may be stated that this gentleman built two vessels at Leith, and put them in motion upon his new improvement, and even sent one of them to the King of Sweden as a present. After this, he thought that an engine could be so constructed as to be applied to work his machinery for the moving of his paddles; and accordingly he employed an engineer to put his plans in execution; but they failed for want of being properly executed. But to give you a more correct account of the manner Mr Fulton, the American engineer, came to the knowledge of steam-boats, that gentleman had occasion to write me about the plans of some machinery in this country, and beg the favour of me to call on Mr Miller of Dalswinton, and see how he had succeeded in his steam-boat plan; and if it answered the end, I was to send him a full drawing and description of it, along with my machinery. This led me to have a conversation with the late Mr Miller, and he gave me every information I could wish for at the time. I told him where, in my opinion, he had erred, and was misled by his engineer; and at the same time I told him, that I intended to give Mr Fulton my opinion on steam-boats. The friends of Mr Miller must have amongst their papers Mr Fulton's letter to me; for I left it with Mr Miller. Two years thereafter I had a letter from Mr Fulton, letting me know that he had constructed a steam-boat from the different drawings of the machinery I had sent him out, which was likely to answer the end, but required some improvement on it. This letter I sent to Mr Miller for his information, which must also be amongst his papers. This letter led me to think of the absurdity of writing my opinion to other countries, and not putting it in practice myself in my own country; and from these considerations I was roused to set on foot a steam-boat, for which I made a number of different models before I was satisfied. When I was convinced that they would answer the end, I contracted with Messrs John Wood and Company, ship-builders in Port-Glasgow, to build me a steam-vessel according to my plan, 40 feet keel, and 10 feet 6 inches beam, which I fitted up with an engine and paddles, and called her the *Comet*; because she was built and finished the year that a comet appeared in the north-west part of Scotland. This vessel is the first steam-boat built in Europe that answered the end, and is at this present time upon the best and simplest method of any of them; for a person sitting in the cabin will hardly hear the engine at work. She plies on the Frith of Forth betwixt the east end of the great canal and Newhaven, near Leith. The distance by water is 27 miles, which she performs, in ordinary weather, in $3\frac{1}{2}$ hours up, and the same down. There were many attempts to make steam-boats in this country before this one, but none of them ever answered the end; and even three years after the *Comet* was set a-sailing, there was a number of our first-rate engineers joined together, and obtained a patent for what they conceived a new discovery on the paddles for impelling the vessel forward. They were disappointed in their plan, and had to return to the model of the *Comet*."

The *Comet* was a vessel of about 25 tons, and her engine, which was a vertical one, exerted about three

Steam Na-
vigation.

horses power. Bell's success immediately excited competition; and a vessel called the *Elizabeth*, 58 feet in deck, and with an engine of 8 horse power, was started by Mr John Thomson on the 9th of March 1815. The spirit of enterprise was now roused, and steam-boats rapidly succeeded each other, every succeeding one excelling its predecessor in power and beauty. No longer timidly confining themselves to the navigation of rivers, the projectors of those steam-ships boldly steered into the deep waters, crossing the channel between Great Britain and Ireland, and performing the dangerous coasting voyages between Glasgow and Liverpool, Leith and Aberdeen, and Leith and London.

The first person who ventured beyond the precincts of a river was in all probability R. L. Stevens of Hoboken. This gentleman had been associated with Chancellor Livingston, previously to the connexion of the latter with Fulton, and had brought his experiments to a successful issue nearly as soon as Fulton and Livingston. Fulton having, however, secured to himself the exclusive privilege of navigating by steam in the state of New York, Stevens at once conceived the bold idea of taking his vessel by sea from the Hudson to the Delaware. To Mr Stevens many of the improvements of steam navigation are to be ascribed. He introduced the modifications of Watt's engine, which we have represented in Fig. 2, p. 693, still in use in American vessels. He introduced engines of long stroke; and, as a necessary consequence, a long crank, and the further peculiarity of upright guides for the piston-rod, instead of the old parallel motion. To him we likewise owe the paddle-wheel with divided boards, by which the resistance of the water was rendered more uniform, and the concussions of the common paddle-wheels avoided. He improved the shape of the American steam-vessels, by substituting for the full round bows and sterns a fine entrance and a fine run. By this, and by making the length of his vessels eight or ten times their beam, he succeeded in raising their rate of sailing from nine to thirteen miles an hour.

Reverting to Britain, we find from the first introduction of Bell's *Comet* in 1813, steam navigation gradually improving as an art. The vessels were, however, of small dimensions, of low proportion of power, and of little speed, until the year 1818, when Mr David Napier directed his attention to the improvement of steam navigation. It is to this gentleman that Great Britain owes the introduction of deep sea communication by steam vessels, and the establishment of post-office steam-packets. In 1818, Mr Napier established between Greenock and Belfast a regular steam communication, by means of the *Rob Roy*, a vessel built by Mr William Denny of Dunbarton, of about 90 tons burden, and 30 horse power. For two winters she plied with perfect regularity and success between these ports, and was afterwards transferred to the English Channel, to serve as a packet-boat between Dover and Calais. Having thus ventured into the open sea, Mr Napier was not slow in extending his range. Soon after, Messrs Wood built for him the *Talbot*, of 120 tons. With two of Mr Napier's engines, each of thirty horse power, this vessel was in all respects the most perfect of her day, and was formed on a model which was long in being surpassed. She was the first vessel that plied between Holyhead and Dublin. About the same time he established the line of steam ships between the stations of Liverpool, Greenock, and Glasgow. For the traffic of these stations he built the *Robert Bruce*, of 150 tons, with two engines of 30 horse power each; the *Superb*, of 240 tons, with engines of 35 horse power each; the *Eclipse*, of 240 tons, with two engines of 30 horse power each. All these were established as regular deep sea traders before

the year 1822, on a station which has not since been surpassed for the power, beauty, and speed of its steam vessels.

Steam Na-
vigation.

In 1822 was built by Messrs Wood on the Clyde, the *James Watt* steam-vessel, to ply between Leith and London. This vessel was of 448 tons measurement, and she carried two engines of fifty horse power each, made by Messrs Watt and Bolton, and completed entirely under the superintendence of Mr Brown of that firm. The *James Watt* was remarkable for having its paddles moved, not directly by the engine, but through the interposition of toothed wheels, so that the number of revolutions of the axis of the engine was greater than that of the paddles. With the exception of the low proportion of its power to its tonnage, the *James Watt* possesses almost all the qualities of the most improved vessels of the present day.

The next great advance in the art was made in 1826, when the first of the leviathan class of steamers, the *United Kingdom*, was constructed. This steam-ship was 160 feet long, 26½ feet beam, and 200 horse power. She was built by Mr Steele of Greenock, and the engines were constructed by Mr Napier. Mr David Napier was also one of the first persons to introduce surface condensation in marine engines. He used it successfully in the *Post-Boy*, a steam-vessel built by him. The condenser was composed of a series of small copper tubes, through which the steam passed towards the air-pump; and, a constant current of cold water encircling the pipes, the steam was cooled and returned into water, which was again sent into the boiler for conversion into steam, without being mixed with the cold salt-water, which, in the usual plan, is injected into the condenser. But, like Watt, Cartwright, and others, who have tried this system both here and in America, he did not find the rapidity of condensation sufficiently great, and he returned to the old system of condensation by jet. Some years afterwards, however, he reverted to this system in peculiar circumstances which rendered it desirable; and, using flat plates instead of tubes, was again perfectly successful, and plied for years with no other condenser. But, like all the other cases where it has been introduced, the advantages of the system were not reckoned equivalent compensation for its disadvantages. The plan of condensation by tubes, again introduced at a recent date by Mr Hall, has been tried in numerous vessels, in some of which it has been abandoned, and in others it still continues to be employed.

The next change introduced very extensively into steam-vessels by Mr Napier, was the use of an upright or vertical steam-engine, or engine of direct connexion. The first engine of Bell was to some extent a vertical engine, inasmuch as the axis of the cylinder and of the crank were placed in one vertical line; but there was no direct connexion between the crank and the piston-rod to the paddle-axle, the communication of motion to it being effected through the medium of toothed wheels. In the common or lever engine the piston-rod acts on a cross-head, the cross-head on side-rods, the side-rods on side-levers, the lever on a cross-tail, the cross-tail on the connecting rod, the connecting rod on the crank-pin, by which through the axle the paddle-wheels revolve. In the engine of direct communication, the side-levers, and some other parts of the train of communication, are removed by a device which enables the piston-rod to be almost immediately attached by a connecting-rod to the cranks of the paddle-shaft. This plan was first adopted by Mr Gutzmer of Leith, who built a vessel called the *Athole*, and another called the *Tourist*, on this principle; but his method, though very simple, was not applicable in ordinary cases; and Mr Napier made se-

Steam Na-
vigation.

veral modifications of the vertical engine, which, according to our judgment, include all the best that have yet been introduced. It does not seem to have been practically established that the engine of direct connexion is preferable to the lever engine; but the plans of Mr Napier appear to have been the best ever adopted.

It is now a considerable time since Mr David Napier relinquished all connexion with such operations on the Clyde; since his retirement, much has been done for the advancement of steam navigation in Britain, and to this work the ship-builders and engineers of the Clyde have contributed their full share. We have already stated that a regular communication by steam was early established between Liverpool and the river Clyde. This establishment has done much for the advancement of steam navigation. It has afforded scope for two extensive companies, who, employing the most eminent steam-engine and ship-builders for the construction of their ships, have produced a very superior class of vessels.

The introduction of wrought-iron hulls for steam vessels, has been the means of introducing a great improvement in the art. This method of construction enables builders to effect a combination of strength and lightness of draught, peculiarly advantageous in some branches of trade and in certain localities. One of the first iron steam-vessels was the *Albarkha*, of 55 tons. It was built to accompany the *Quorra* in the expedition to the Niger in 1832, and gave very great satisfaction. The builders of the *Albarkha*, Messrs Laird of Liverpool, immediately afterwards commenced another vessel, the *Garry-Owen*, destined to run between Limerick and Kilrush. The length of this vessel was 125 feet on deck, its beam 21 feet 6 inches, and its engines were fifty horse power each. The *Garry-Owen* was driven on shore, with many other vessels, in the great hurricane which happened about that time, and alone escaped uninjured. This, and other evidence of the power of iron vessels to withstand the casualties of the sea, so raised them in the estimation of builders, that their number was rapidly increased, and their size greatly extended.

For a long period there had been much speculation about the practicability of navigating the Atlantic by steam. So early as 1791, and while the steam-boat was yet in embryo, Fitch, the American, boldly predicted that sailing vessels would soon be superseded in transatlantic navigation. In 1819, an American steam-ship, the *Savannah*, of 300 tons' burden, arrived at Liverpool direct from the United States, having accomplished the passage in 26 days, partly steaming and partly sailing; and nearly ten years after, the *Curaçoa*, an English built vessel of 350 tons and 100 horse power, made more than one successful run in the same manner, between Holland and the Dutch West India colonies. Men of science, however, endeavoured to demonstrate that the navigation of the Atlantic by steam-power alone, was the dream of a visionary, and the tide of public opinion seemed to set in in the same belief; but a strong undercurrent was at work, and in 1838 the following advertisement appeared in the daily papers: "*Steam to New York*. The well-known steam-ship, *Sirius*, Lieutenant Roberts, R.N., Commander, is intended to leave London for New York on Wednesday 28th March, calling at Cork harbour, and to start from thence on Monday the 2d of April, returning from New York the 1st of May." Thus, a company of merchants was found sanguine enough to disregard the demonstration of the impossibility of an American voyage, and actually to advertise not only the day of sailing, but also the days of arrival and return. The *Sirius* was not expressly built for transatlantic navigation; she belonged to the St George Steam-Packet Company, and had run with a good repu-

Steam Na-
vigation.

tation between London and Cork. Her tonnage was about 700 tons, and her engine about 320 horse power. Although advertised to sail on March the 28th, circumstances delayed her departure till the morning of the 4th April, when she started at ten o'clock, with 94 passengers. Though first in the race, she was only three days in advance; for on the 7th of the same month, the *Great Western*, built and fitted expressly for the purpose, followed her. In the interval, between the sailing of these vessels and the reports of their arrivals, much doubt prevailed as to the possibility of their accomplishing their task in safety, and the uncertainty was increased by vessels having arrived from America at ports in Britain, without having encountered either of the steamships; people having, for a moment, forgotten that there were more roads than one across the Atlantic. They were at length, however, spoken with by the *Westminster*, the *Sirius* on the 21st, within six hours' sail of New York, and the *Great Western* on the 22d; and in due time, reports of their having reached New York arrived, the *Sirius* on the 22d, being 17 days clear on the passage, and the *Great Western* on the 23d, being 15 days. The *Sirius* again sailed on her homeward passage on May 1st, afternoon, and the *Great Western* on May 7th, and they arrived, the first on the 18th, and the latter on the 22d, being 16 and 14 days respectively. The average speed, and expenditure of fuel of the *Great Western* was as follows. The whole distance run from Bristol to New York was 3125 miles, averaging each day 208 miles, each hour 8.2 miles; the distance run in returning from New York 3192 miles, each day 213 miles, each hour 9 miles nearly. She departed with 860 tons of coals, and on her arrival at New York she had 205 tons remaining. She left New York with 570 tons of Newcastle coals, and had on board when she arrived at Bristol 178 tons. Her average daily consumption was 27 tons; and, with the expansion valves up, 32 tons. In page 707 there is given a table exhibiting a comparative view of the size and power of six of the largest of the transatlantic vessels.

The practicability of transatlantic navigation being thus fully demonstrated, preparations for its continuance on a gigantic scale commenced, and the *British Queen*, the *President*, and other vessels of enormous size, were launched in rapid succession. In addition to these, the offspring of a state of peace, steam war vessels, of great size, are daily constructing, and call for the highest ingenuity of the ship-builders and engineers, in adapting them for taking the advantage of their sails as well as of their steam-paddles.

While the art was thus rapidly advancing, many ingenious men were making attempts to improve the form of the paddle-wheels, or to substitute for them some other impelling apparatus. Of the improvements in the paddle-wheels themselves, we shall have occasion to speak in the sequel. We shall, therefore, in this place, give some account of the most important of the substitutes, the Archimedes screw propeller. The idea of impelling a vessel by means of a screw of a large diameter, lying in the direction of the boat's motion, was originated some considerable time ago; but its first successful application was to a vessel named the *Archimedes*, constructed under the direction of the patentee of the screw, Mr Smith. From an interesting report of experiments made with this vessel by Captain Chappell, R.N., we condense the following statement:—The burden of the *Archimedes* is 237 tons, its mean draught of water 9 feet 4 inches. The diameter of the engine cylinder 37 inches, and the length of stroke 3 feet. The screw propeller consists of two half-threads of an 8 feet pitch screw, 5 feet 9 inches in diameter; each is therefore 4 feet in length, and they are set diametrically

Steam Na- opposite to each other on the propeller shaft, at an angle
vigation. of 45 degrees to the shaft. The propeller is placed lon-
gitudinally in a hole cut in the dead wood, immediately
before the rudder, the keel being continued under the
screw. The average performance of the engines is 26
strokes per minute, and the revolutions of the screw in
the same time 138 $\frac{1}{2}$. If there was no slip or recession,
the vessel ought to advance 8 feet for every revolution of
the screw, or 12.60 miles per hour. The utmost speed
ever obtained by her, under the power of steam alone,
was 9.25 nautical miles per hour, showing a loss by re-
cession of rather less than $\frac{1}{6}$ th, under the most favourable
circumstances. It is necessary to state that the Archi-
medes is not a fair exemplar of the screw-propelling
principle, its steam-power being insufficient to drive a
screw adapted to the size of the vessel.

The advantages of this species of propeller appear from
Captain Chappell's statement to be these:—1. It occupies
a position in the vessel in which it is not liable to injury,
and in which it materially augments the power of the helm,
enabling the vessel to be turned round and round in
circles gradually smaller, until at length it seems to re-
volve on a pivot. 2. It retains its efficiency of action,
even in heavy seas, the rolling, pitching, or lurching of
the vessel not materially affecting it. 3. It offers little

obstruction to the speed of the vessel, when the sails Steam Na-
alone are employed. When to these are added the saving vigation.
of expense, which is said to be great, and the removing
the top-weight and unsightly paddle-boxes, we are of
opinion that there is enough in its favour to recommend
its further trial.

We have now traced the art of steam navigation from
its first suggestion to its present state of high perfection.
We have overlooked, it is true, much that is interesting
in the minute progression of the art; but we have en-
deavoured to mark its greater advances. We have seen
its advancement in the short period of a quarter of a
century, from the canal boat experiment of Symington,
and the three horse steam-boat of Bell, to the construction
of the monster ships, the British Queen and the President,
of 500 and 600 horse power. When, in 1820, steam-
ships were first used for conveying merchandise, as well
as passengers, the tonnage of the whole of the steam-
traders amounted to only 505 tons. In 1821, it amounted
to 36,194; in 1822, it had reached to 101,744 tons; and
thus advancing, it had arrived, in 1836, at the pro-
digious amount of 5,429,226 tons. The number of ves-
sels of the mercantile marine, with their power and ton-
nage, is exhibited in the following table.

*An Account of the Approximate Number, Tonnage, and Power of Vessels belonging to the Mercantile
Steam Marine of the United Kingdom and its dependencies, at the close of the year 1839.*

SIZE OF VESSELS.	Total Number of Vessels, according to the Custom- House Returns in 1838.	Total Registered Tonnage.	Tonnage of Engine-Room, &c., not Re- gistered at the Custom- House.	Total Computed Tonnage.	Total Computed Amount of Horse power.	Average Computed Power per Vessel.	Average Computed Tonnage per Vessel.
Under 50 Tons . . .	No. 256	Tons. 6,106	Tons. 10,816	Tons. 16,922	Horse power. 6,400	Horse power. 25	Tons. 66
From 50 to 100 Tons . .	145	10,267	7,458	17,725	6,866	47	122
100 „ 150 „ . .	84	10,034	7,761	17,795	7,483	90	211
150 „ 200 „ . .	63	10,982	7,147	18,129	7,560	120	287
200 „ 300 „ . .	76	16,654	10,839	27,493	11,188	147	361
300 „ 400 „ . .	41	14,247	7,580	21,827	10,914	266	532
400 „ 600 „ . .	10	4,488	3,506	7,994	3,000	300	769
679 „ . .	1	679	661	1,340	450	450	1,340
1,053 „ . .	1	1,053	810	1,855	500	500	1,855
Number of vessels Regis- } tered in 1838 }	677	74,510	56,378	131,080	54,361	...	...
Not Registered }	83	4,154	5,484	9,638	2,129	50	116
Total Number in Great } Britain and Ireland, } 1838 }	760	78,664	62,062	140,718	56,490	...	...
Isles of Guernsey, Jersey, } and Man, 1837 }	6	832	618	1,450	600	100	241
British Plantations, 1837 }	44	8,411	7,253	15,664	6,160	140	356
Total	810	87,937	69,933	157,840	60,840	..	...

(B. S.)

THE THEORY AND PRACTICE OF MODERN STEAM NAVIGATION.

There is perhaps no popular error more injurious to the
welfare of a mechanical nation, like our own, than the no-
tion that theory is opposed to practice; and there is no
subject in which this error has ever been more disastrous
than in steam navigation, and naval architecture in general.
It is by the combination of theory and practice that most
is to be accomplished; and it may be hazarded as a general
assertion, resting on all past experience, that the best

promoters of the public welfare are—that theoretical man
who has made himself best acquainted with the practice
of his art, and that practical man who has acquired the
greatest knowledge of its scientific principles. There is
no art which does not attest this truth, and none attests
it more than steam navigation. It is admitted, that out
of every three steam vessels that are built, two fall very
far short of fulfilling the intention with which they were

Steam Na- constructed. We believe there is no error which it may be possible to commit in steam navigation, that has not already been perpetrated again and again.

To construct a perfect steam-vessel, it is necessary first of all to make a perfect ship; secondly, to construct a perfect steam-engine and boilers of a very complex description; thirdly, to apply a propelling apparatus of the most appropriate description; and finally, to combine all of these in a perfect and well-proportioned whole. Now, to construct a perfect ship, is itself a problem of the highest order, requiring a combination of the most profound resources of analysis, with the highest practical sagacity; a problem on which the reasoning of the mathematician, and the tact of the artist, have long been engaged, with few examples of complete success. To construct a sufficient, effective, powerful, durable, and safe engine and boilers for marine purposes, is a problem more easy, yet one in which there has been encountered continual failure. Then, the means of propelling the vessel over the element on which it floats, give rise to questions in the resistance of fluids which all the resources of hydrodynamic science, in the hands of the ablest mechanical philosophers of the last century, have failed to resolve. Then, last of all, the combination of all of these together, in the best possible way to bring about the precise effect desired, is a problem still more arduous; and all the skill of the analyst, the geometer, the mechanical philosopher, of the naval architect, the engineer, the mechanic, and the sailor, if combined in a single individual, or concentrated on a single object, are not more than sufficient to the arduous task of directing the wealth, enterprise, and resources of this country, in the attempt to render available to her own prosperity, and the interests of the human race, this most admirable of all her creations.

In the following enquiry, we shall soon see that neither practical experience without systematized knowledge, nor superficial theory ignorant of practical wants and practical means, will suffice to ensure success. Both physical science and practical sagacity will, in the art of steam navigation, find enough to exhaust their united resources.

We regret that we cannot record in the present work, that at this day the science of steam navigation is constructed and can be presented to our readers. Even the elementary principles of hydrodynamics are yet to be learned, before we can apply them to the ends of steam navigation. What seems the law of a fluid to-day, to-morrow shows to be a plausible fiction, or doubtful verisimilitude. How then can it be expected that a science should be determined, when its very foundations are yet to be laid? We shall, however, endeavour to generalize what we with certainty know, convinced that a clear statement of our ignorance is often the stepping-stone to truth. The steam-ship consists of three integrant parts: the marine-engine, with its boilers, by which the moving power is furnished; the propelling apparatus, by which it is rendered locomotive; and the ship itself, which contains both. We shall consider each apart, and then their combination.

The Marine Steam-Engine.—The marine steam-engine is of a structure more complex than the common fixed steam-engine, inasmuch as its function is locomotive, and it differs from a land-engine in those peculiarities which adapt it to the unstable nature of its support. He who looks at the ponderous masses of matter that form and sustain the shock of a powerful engine on land, the beams of iron, the blocks of stone, the deep buttresses, and the powerful walls which form its bed, on which it is adjusted at once with the greatest accuracy and power,

and which it nevertheless causes to quiver and tremble by its giant strokes, will readily understand the incredulity with which the first projectors of steam navigation were regarded.

The earliest application of the steam-engine was to the pumping of water. We find that when it was first used to the effect of making machinery revolve, the great lever of the pumping-engine was retained. So was it in the application of the steam-engine to navigation; and the marine steam-engine, most generally used at the present day, both here and in America, is called the beam-engine, or lever-engine.

The first of the following diagrams represents the beam-engine, or lever-engine, as used on land to turn round machinery; the second represents the lever-engine, as used in America to give revolution to the paddle-wheels of a steam-boat; and the third represents the lever-engine of British steam-vessels.

Fig. 1.

Fig. 2.

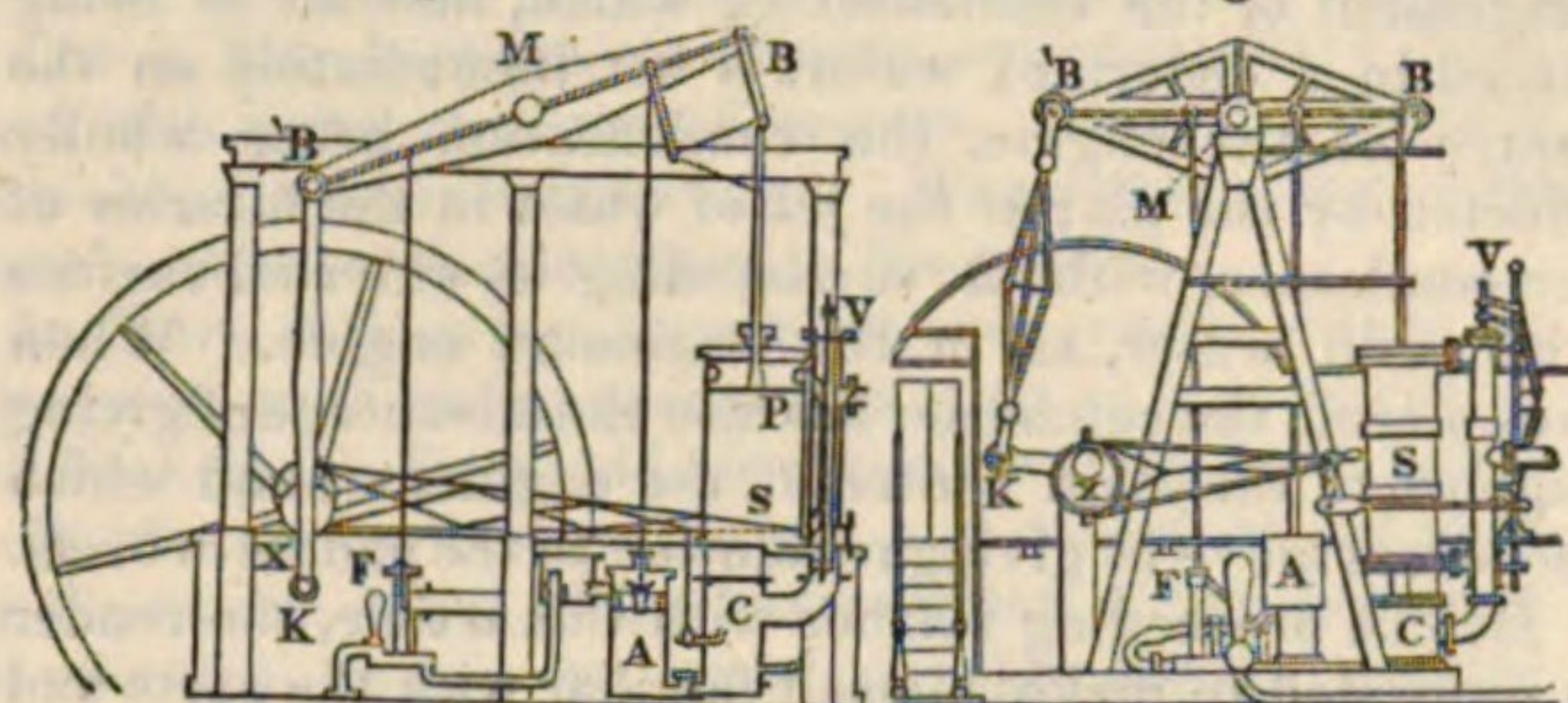
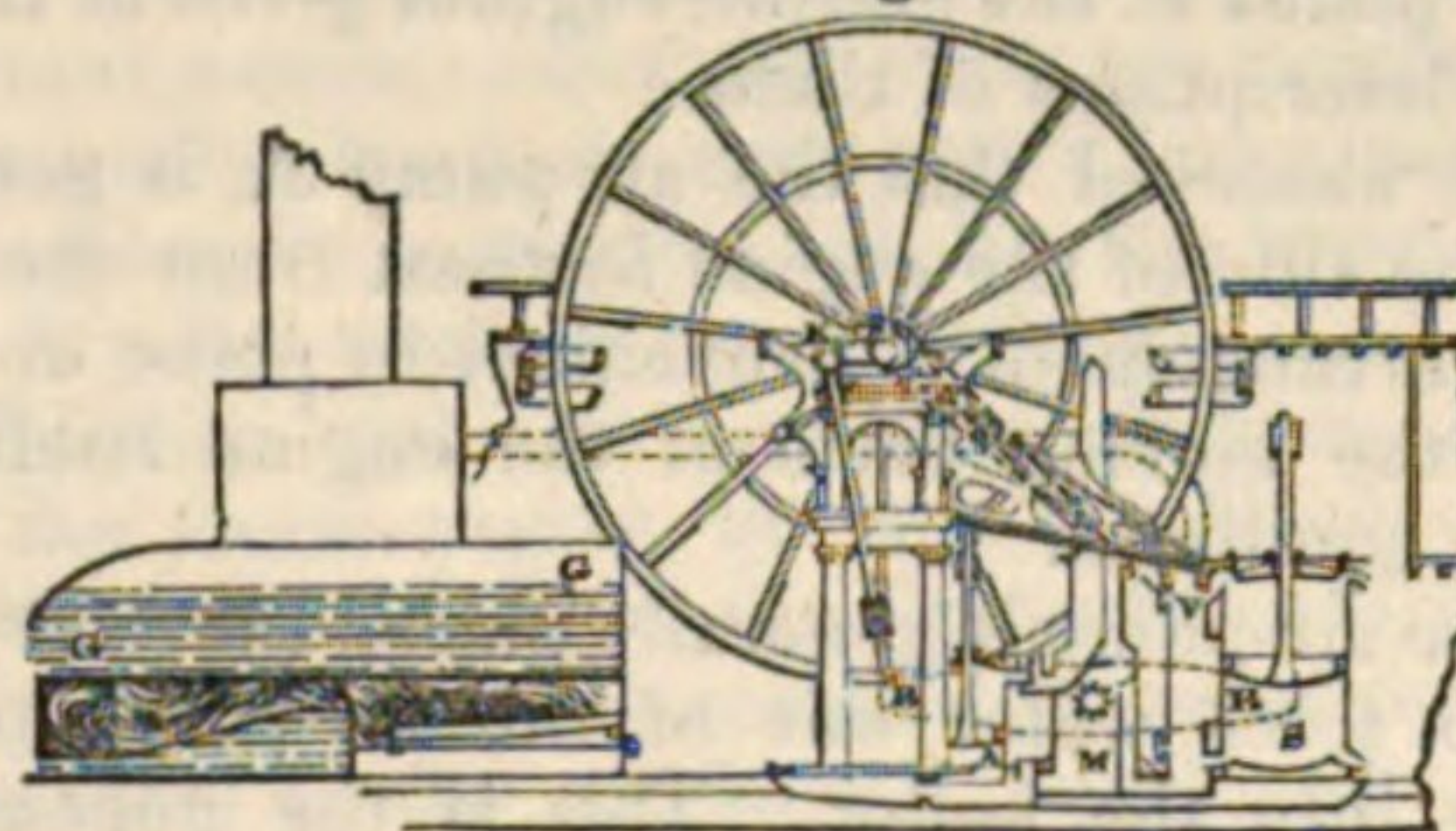


Fig. 3.



In all of these figures, S represents the place of the steam-cylinder, in which, by the alternate action of the steam on opposite sides of the piston P, that and the piston-rod P B are forced alternately to the top and bottom of the cylinder; and so the end of the lever or great beam B B is carried up and down around the centre M, carrying with it the connecting rod K B', by whose reciprocation the crank-pin K, of the crank radius K X, is carried round on the great revolving shaft X; which, in the case of the marine engine, is the axis of the paddle-wheel, and in the case of the stationary engine, is the axis only of the fly-wheel. V is the place of the valves by which steam is admitted from the boiler into the cylinder, and, after having done its duty, is educted into the condenser C, where, by a jet of cold water constantly playing, it is immediately condensed into water of the seventeen-hundredth part of its bulk, and so leaves the cylinder empty, *i. e.* nearly a perfect vacuum; and as this condensing receptacle would soon, by the jet of cold water flowing into it, and the accumulation of condensed steam, be filled with water and its evolved gases, the air and water are pumped out at each stroke of the engine by the air-pump A, worked from the lever or working-beam B B, and so the vacuum is kept perfect and the condenser effective. The feed-pump F replenishes the boiler G with some of the water extracted from the condenser, at a temperature of about 90°, and so supplies the deficiency caused by the con-

Steam Na-
vigation.

Differ-
ence be-
tween the
Marine
Engine and
the Land
Engine.

tinual evaporation of the water, at the rate of 6 gallons for each horse power every hour.

The differences between the arrangements of the marine steam-engine used in Great Britain, and the land steam-engine, are chiefly these: the lever or great beam, which, in the land-engine, is above the top of the engine, and which in large engines is generally composed of a pair of thin deep beams of cast-iron, united side by side into one; this single beam is brought down in the marine engine to the bottom of the engine, or rather one-half of the great beam is placed on either side of the cylinder, the two being connected together from the opposite sides of the engine, so as to act simultaneously as a single lever. This form of engine, sometimes applied to other purposes as well as to navigation, is called, from this disposition of the working beam, the side lever engine.

Another peculiarity in the marine-engine, sometimes however adopted in land-engines, is the place and arrangement of the condenser C, which, instead of being placed in a cistern of water, is set immediately on the centre of the engine, the condensation being wholly effected by the play of the jet of water in the interior of the condenser, without surrounding its external surface with cold water, as in the stationary engine. When thus placed, the condenser has also the advantage of giving support to the main centre of the engine, around which the levers move in giving revolution to the paddle-wheels.

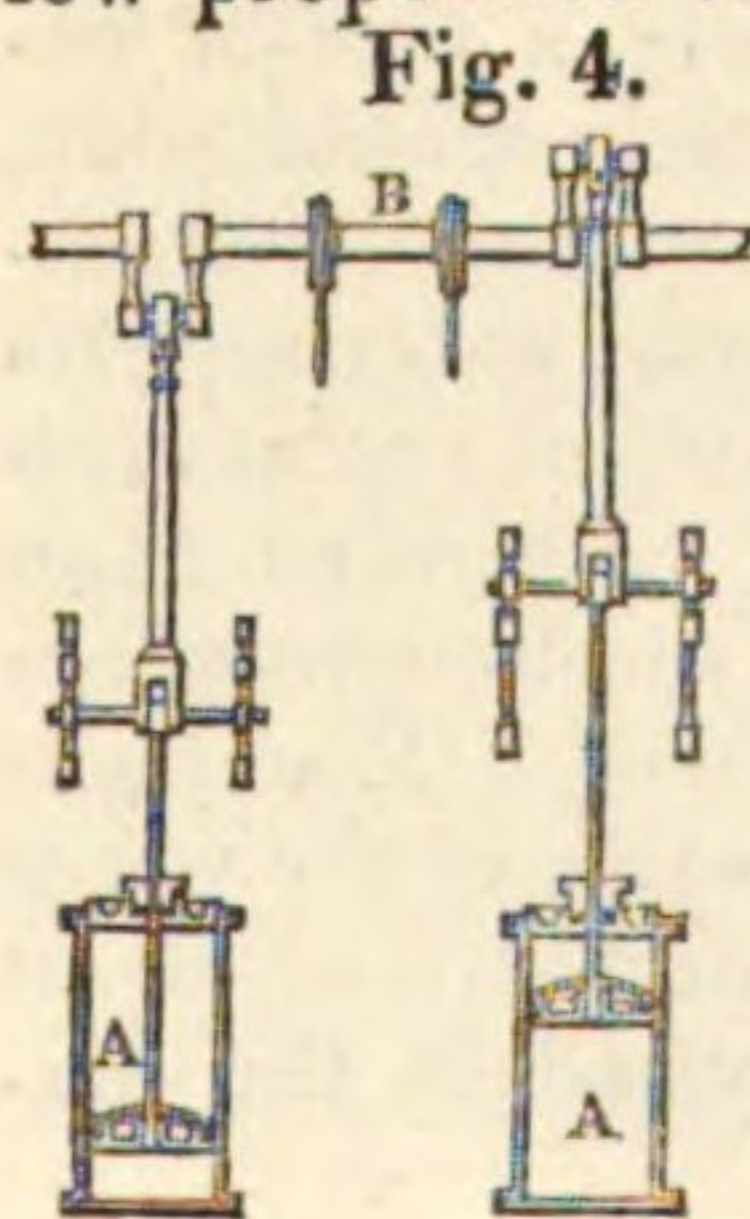
Before proceeding further with this article, the reader is requested to make himself familiar with the parts and arrangements of the engine already described, by referring to the plates of the marine-engines given at the end, and to the descriptions of them.

It will be observed that the air-pump A is generally placed on the side of the engine furthest from the cylinder. This arrangement is convenient in point of room, and keeps the moving parts of the engine itself more perfectly in equilibrio.

Beside the air-pump is generally placed the feed-pump, designed to force water out of the air-pump or discharge-pipe into the boiler. This is the general disposition of parts, which the reader will easily be able to recognise in the plates given with this article.

Although the lever-engine is the form most commonly employed for marine purposes, it is by no means the only form. Very many attempts have been made to obtain engines more compact and of less weight and bulk than the lever-engine. These are distinguished from the lever-engines by the names vertical engines, steeple-engines, and engines of direct connexion. It is still doubtful whether any of them, except in very peculiar circumstances, are practically to be preferred to the lever-engine; on the contrary, objections of a serious nature are alleged against them.

We have already seen that the first steam-boat, the Comet of Mr Bell, had a vertical engine. It was remarked of this vessel that the strain of the engine on the vessel was very small; but this has been attributed to the low proportion of power to the tonnage of the vessel.



The first steam-vessel whose engines we had the pleasure of seeing, had a pair of vertical engines, made by Gutzmer of Leith; the paddle-shaft B being directly over the axis of the cylinders A, as in figs. 4. and 5.

Modifications of this plan of direct or imme-

mediate connexion have been recently tried on a larger scale; but the method has the disadvantages of admitting only a short stroke and a short connecting rod, and requires that the height of the axis above the bottom of the cylinder should be at least three times the length of the stroke. Thus, one of the extremes, too short a connecting rod, too short a stroke, or a paddle-axis too high above the floor of the vessel, is incurred.

To obtain the same object without incurring those evils, many descriptions of engine have been contrived. The following admits of placing the paddle-axis at little more than double the height of the stroke of the engine, and gives a connecting rod of $1\frac{1}{2}$ or 2 times the stroke. The piston-rod P is inserted into a cross-head d d, to the extremities of which two vertical rods d e, d e, are attached. With the lower extremities of these rods the side-rods g f, g f, are connected; the upper ends of these side-rods are attached to the cross-head g g, to the centre of which the crank-rod is attached.

Fig. 6.

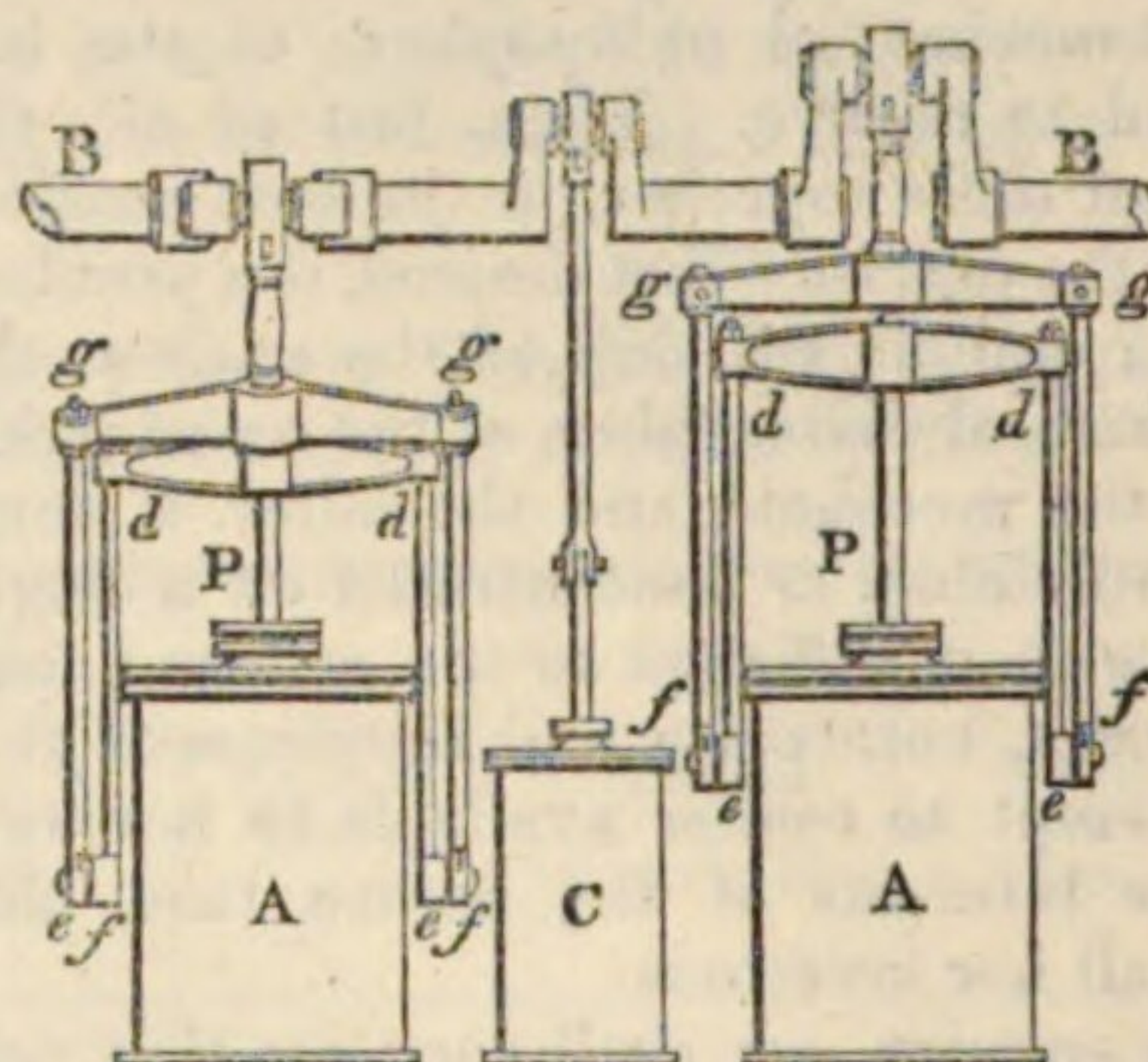
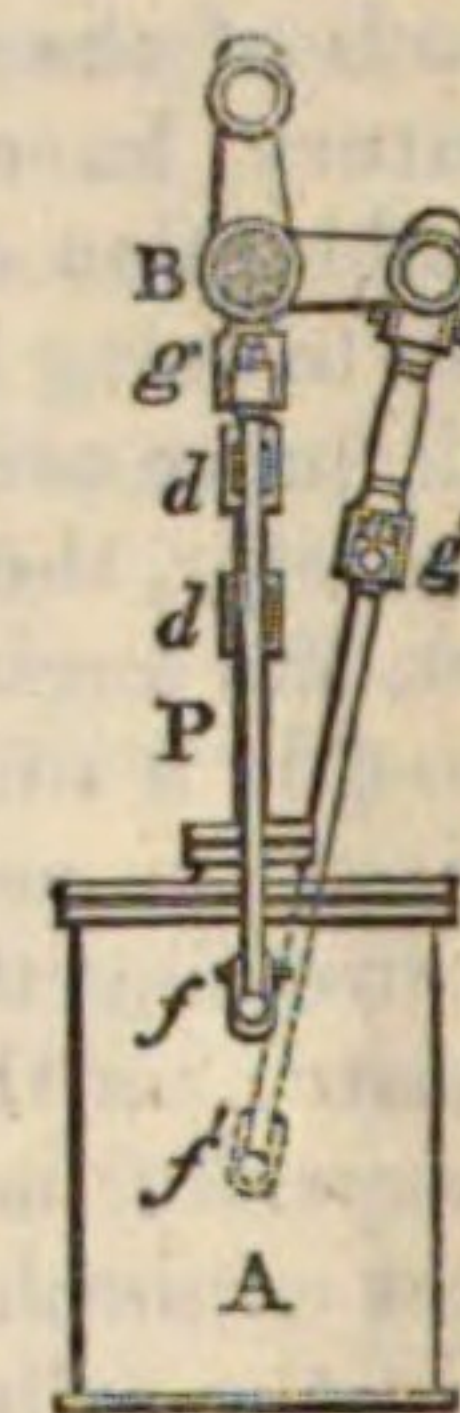


Fig. 7.



This species of engine has the great disadvantages of a multiplicity of shafts, bearings, and cranks. It was afterwards simplified by Mr David Napier in the manner represented in the following figures; viz. by uniting into one forked cross-head each cross-head with its side-rods.

Fig. 8.

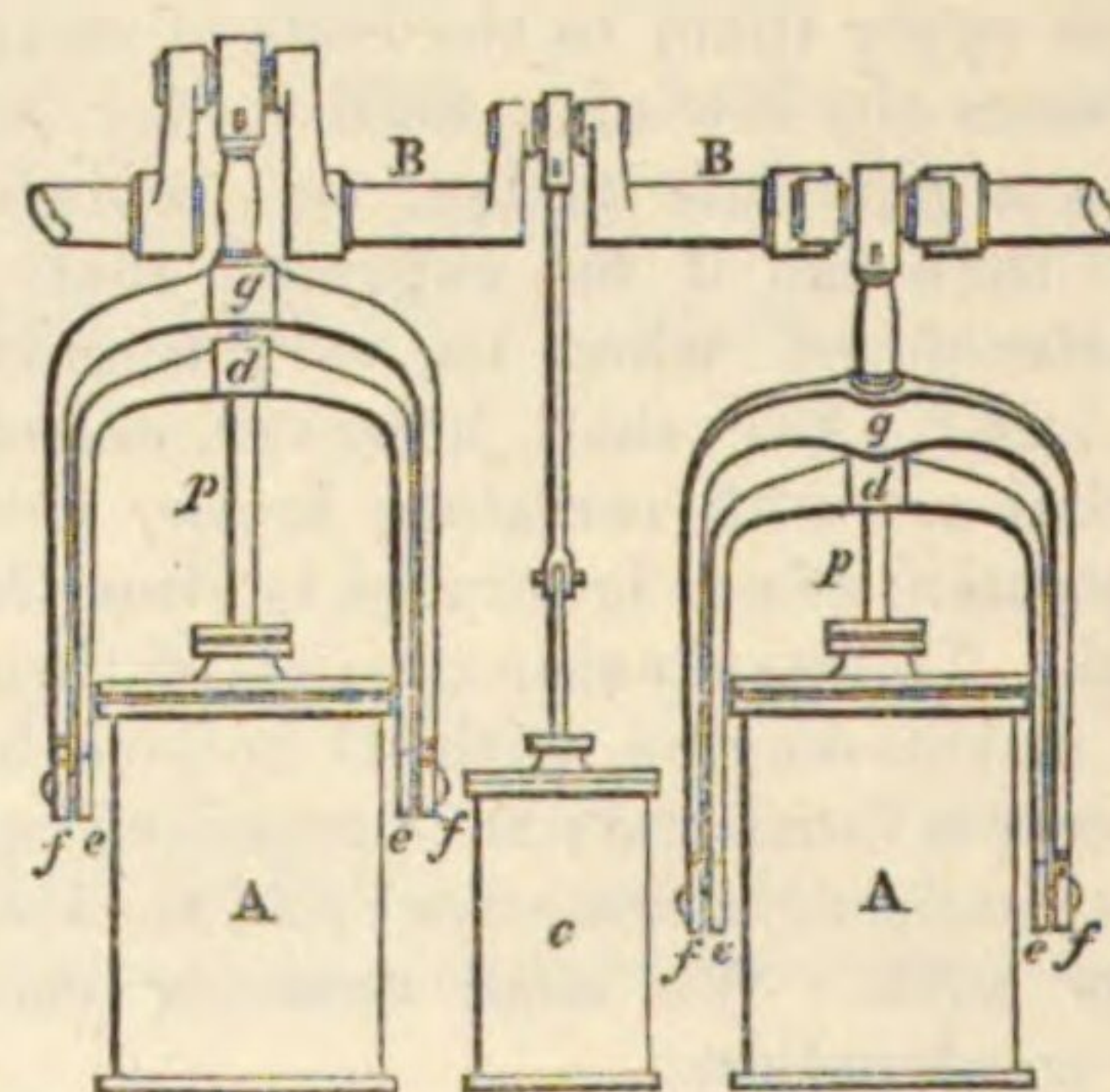
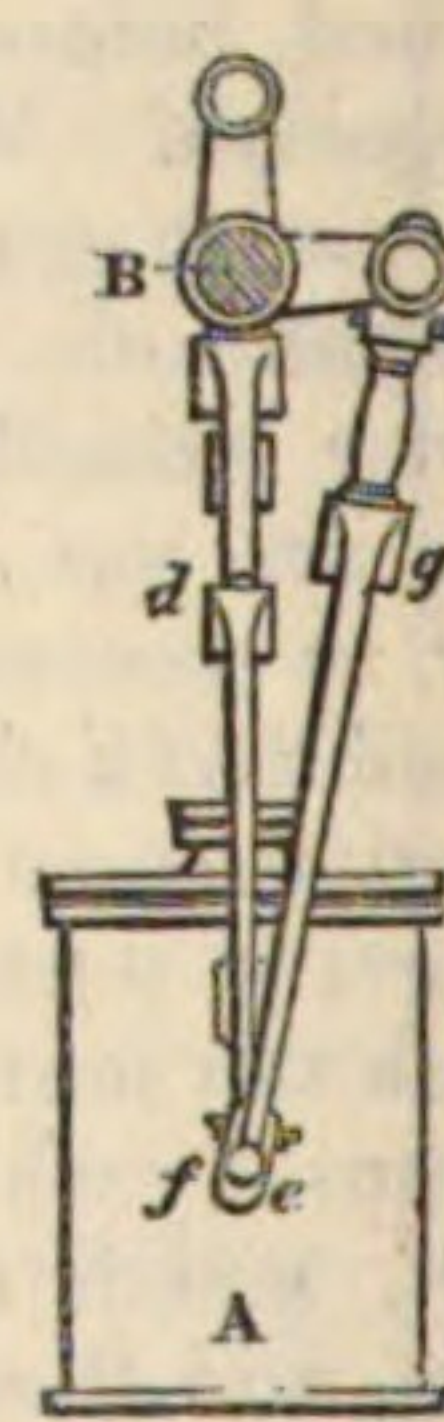


Fig. 9.



Even thus, however, limits are placed on the length of stroke and height of shaft, so as to give rise to inconvenience in many circumstances. To remedy these evils, Mr Napier appears to have invented the following class of engines, to which the cant term of steeple-engines appears to be sufficiently appropriate. In the steeple-engine the piston-rod is made forked or divaricated, so as, passing round the shaft, to rise above it to a considerable height, from which again descends the connecting rod to the crank. The following example is that

Steam Navigation. of the engine of a vessel named the Clyde, the first of the kind we ever saw :—

Vertical Marine Engines.

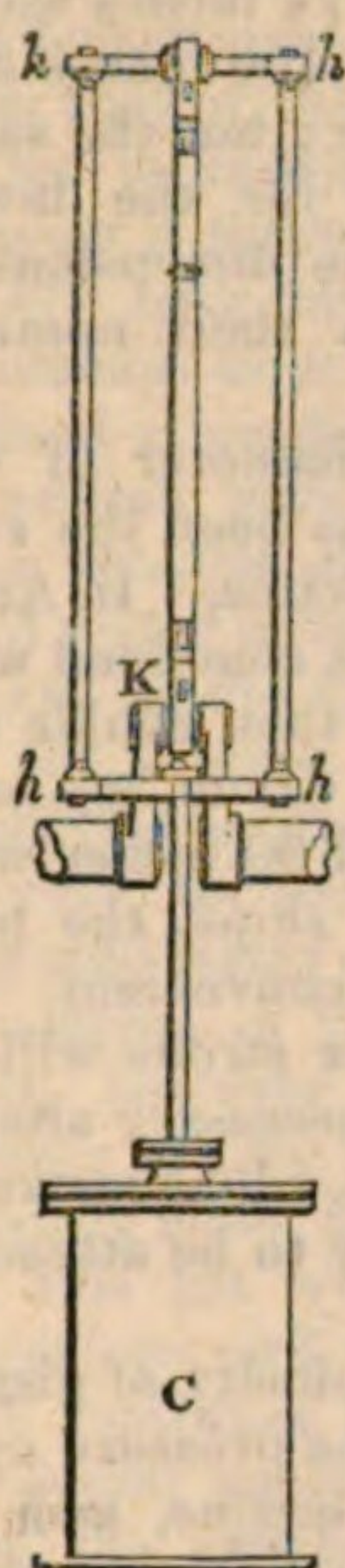


Fig. 10.

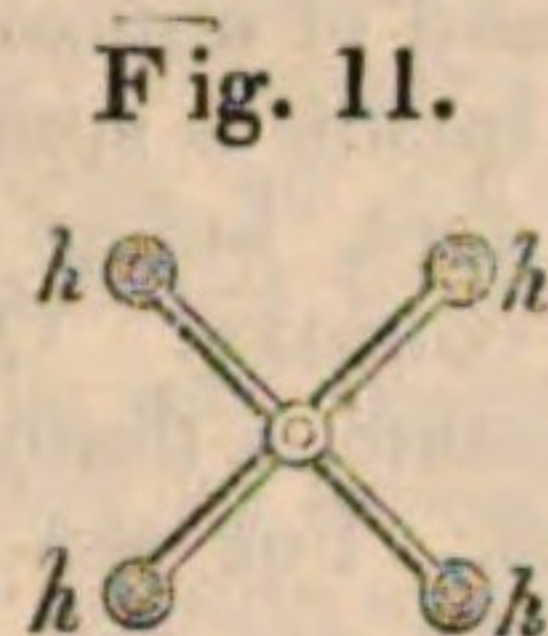


Fig. 11.

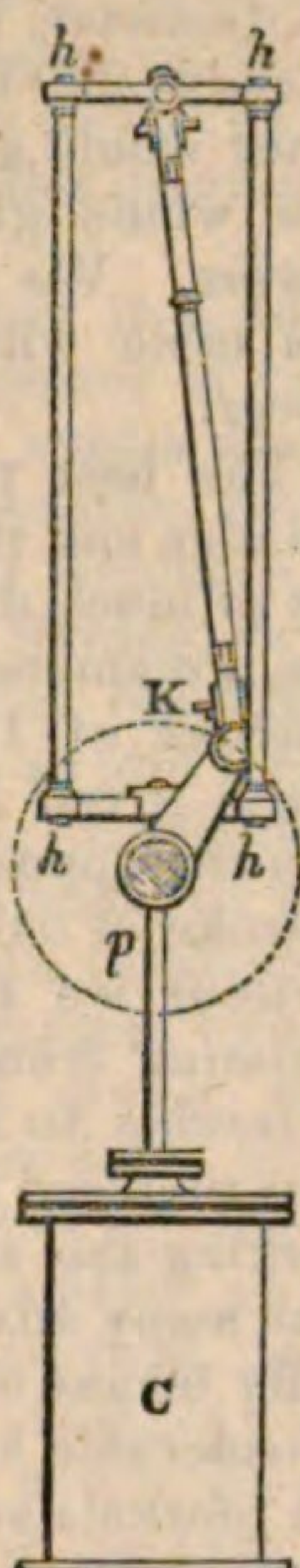


Fig. 12.

The top of the piston-rod carries a quadripartite cross-head *h h*, on each end of which stands a pillar *h h*; these four pillars again unite in another quadruple cross-head, sustained upright by a vertical guide; and it is from this summit that a connecting rod descends to the crank *h*. We believe that this principle of continuing the piston-rod round the axis by a forked frame was first devised, at the end of the last century, by Trevithic, the famous high-pressure engineer, and by him applied to steam-carriages. It is drawn in his patent specifications.

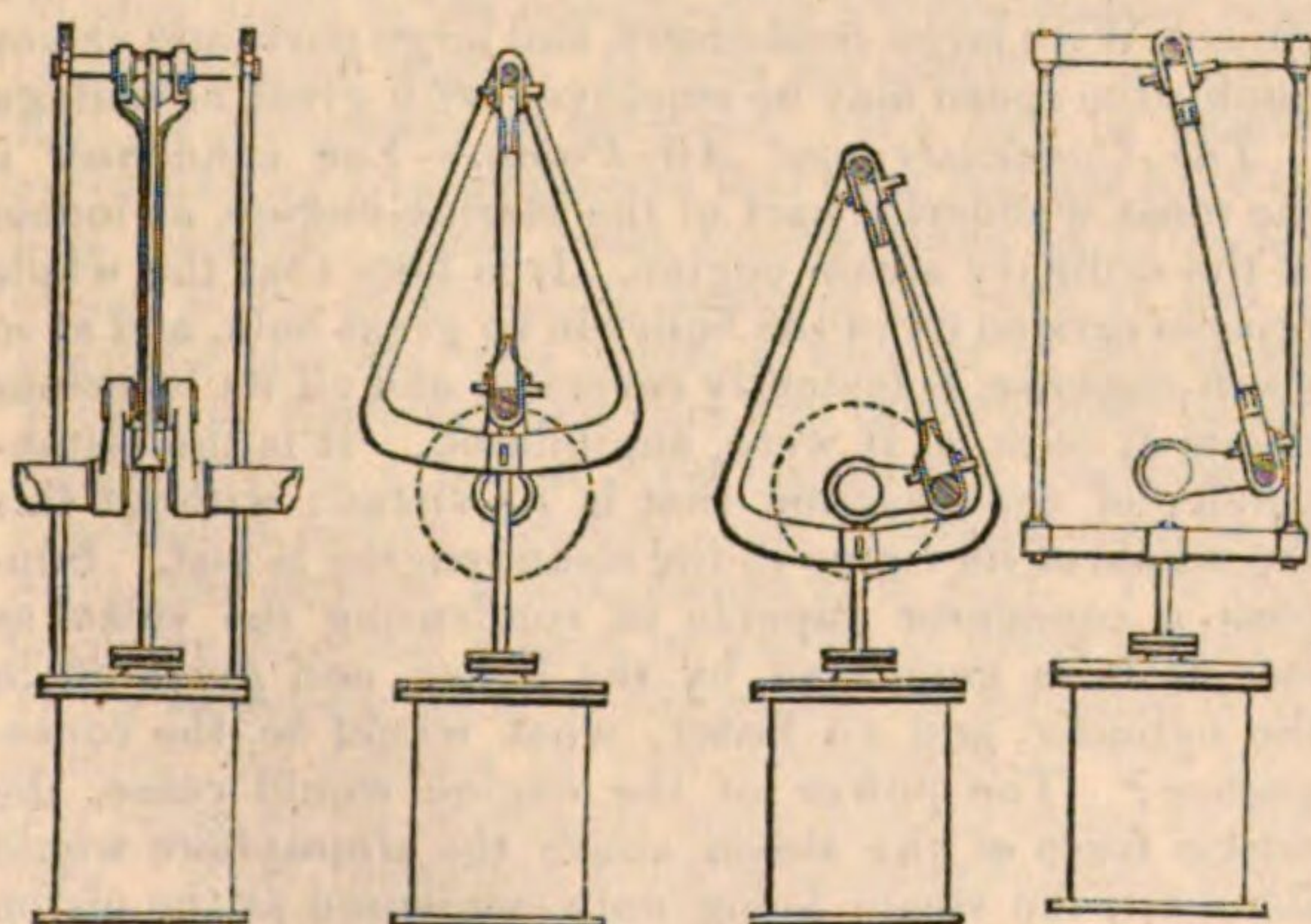
After passing through a great variety of phases, the steeple-engine appears to have settled down into the two following shapes. In figs. 14 and 15, the piston-rod is seen united to a triangular frame, from the apex of which the connecting rod descends to the crank. In fig. 16, this frame is shown to be square, and fig. 13 is the side view of both varieties.

Fig. 13.

Fig. 14.

Fig. 15.

Fig. 16.



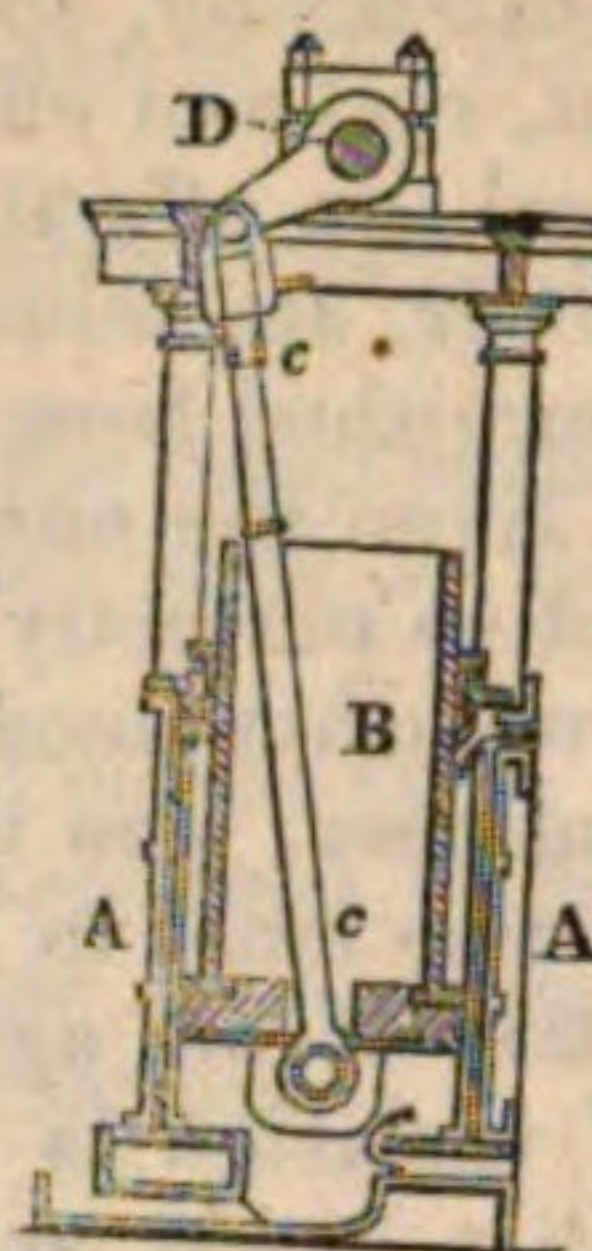
Another method of accomplishing the direct connection without encumbering the deck, has twice been patented: in the last instance by Mr Humphreys. It may

be called the trunk-engine. The axis is placed at the height of half the stroke, or more, above the cylinder, and a connecting rod unites immediately the crank-pin with the centre of the piston. In this way the connecting rod, passing through the top of the cylinder, would allow the steam to escape but for a large trunk or casing with which it is surrounded, and which, passing through a chasm of large area conceived to be steam-tight, rises and falls with the piston to which it is attached. In fig 17, *A A* is the cylinder: to its piston is attached a trunk *B*, which works through a stuffing-box in the cylinder cover; to the piston the connecting rod *c c* is attached. Fig. 18 represents the top of the cylinder *A A*, with its stuffing-box and the trunk *B*.

Fig. 17.



Fig. 18.



Steam Navigation.

Humphreys' Engine.

For a like purpose, oscillating cylinders have been used with some measure of success. Rotatory engines have been unsuccessfully tried. The reader may now examine the vertical engines in the plates.

In short, it does not appear that any vessel, either on a large or small scale, constructed with an engine different from the ordinary side lever engine, has been found to be practically superior to it; and therefore we shall for the future speak of the lever-engine of the ordinary construction, when we treat of the marine steam-engine, unless when another species is expressly mentioned. The lever-engine possesses three advantages of an important nature:—first, its parts are nearly in equilibrio; secondly, its basis embraces a large part of the vessel's bottom for strength; thirdly, the lever presents great facility for working its appendages.

The Cylinder of the Marine Steam-Engine.—The cylinder of the steam-engine being that portion of its apparatus, by means of which the elastic force of the steam is directly applied to the mechanical arrangements by which the force of the machine is developed, is therefore the principal member of the engine, on the size of which its powers and the dimensions of the other parts depend.

It is according to the dimensions of the cylinder that an engine receives its denomination, and is bought or sold. An engine is called a 10, 20, 50, or 100 horse-power engine, according to the number of inches in the diameter of the cylinder. It is not to be expected, however, that every steam-engine will develop the power of a given number of horses, simply because it has a cylinder of a given number of inches. This depends equally on the proper proportion, construction, and condition of all the other parts, without which the engine will be incapable of doing its proper duty. The engines of some makers will develop double the power of those made by inferior engineers, even although in name and dimensions identical. Hence, the dimension of cylinder is taken according to a rule somewhat arbitrary, of the value both dynamical and pecuniary of the engine under the term nominal power; and the actual efficiency of the engine under given circumstances, is called the real or effective power. Hence an ambiguity is incurred in speaking of the relative powers of engines, when it is not determined whether the real or nominal power is referred to. An engine of 100 horse power, which ought to be capable of giving out an effective power of 100 horses, may, from bad workmanship, bad arrangements, or modified circumstances, only give out the real power of 50 horses; and an engine of the same dimension of

Steam Na-
vigation.

Cylinder
of the
Marine
Engine.

cylinder, and of the same nominal power, but of better construction, may give out, and frequently does give out, real and effective power equal to that of 150 horses. Real or effective power, and nominal or mercantile power, are seldom identical, and should always be distinguished from each other.

Even the nominal or mercantile standard of power is not so perfectly invariable as may be desired. It varies a few inches according to the practice or policy of the engineer, who is frequently called upon to give an inch or two more in his mercantile dimensions, than the strict letter of his agreement might demand. Another cause of variation is this, that some engineers will prefer to sell a larger actual dimension under the name of a less number of horse power, that their engines of a given nominal power may apparently do more work than those of other people. It is a third cause of variation, that some engine-makers give more than the actual dimension belonging to the power, in order that, under even the most unfavourable circumstances, the possessors of the engine may derive from it more than the full measure of the actual effective power which they require.

The following table has been constructed from a comparison of the practice of the most eminent marine steam-engine makers, with the principles of their construction. But under the dimensions given, the engines of best construction will give out from one-fourth to one-third more than their nominal power. We know, for example, that a cylinder of 74 inches diameter has been constructed under the designation of 200 horses, whereas its proper nominal power is above 225 horses, and its actual effective power, as given out in the ship, was more than 300 horses. The contraction H.P. is generally used instead of the words horse power.

Table of the Dimensions of the Cylinder of a Marine Steam-Engine of given Horse power.

Nominal Power.	Dimensions of Cylinder.	
	Diameter (within.)	Length of Stroke.
10 H.P.	20 Inches.	2 Feet 0 In.
15 "	24 "	2 " 2 "
20 "	27 "	2 " 6 "
25 "	30 "	2 " 10 "
30 "	32 "	3 " 2 "
35 "	34 "	3 " 3 "
40 "	36 "	3 " 6 "
45 "	38 "	3 " 9 "
50 "	40 "	4 " 0 "
60 "	43 "	4 " 3 "
70 "	46 "	4 " 6 "
80 "	49 "	4 " 9 "
90 "	52 "	5 " 0 "
100 "	55 "	5 " 6 "
110 "	57 "	5 " 6 "
115 "	57 "	5 " 9 "
125 "	59 "	6 " 0 "
130 "	60 "	6 " 0 "
150 "	62 "	6 " 3 "
165 "	65 "	6 " 6 "
175 "	66 "	6 " 6 "
200 "	70 "	7 " 0 "
225 "	73 "	7 " 3 "
250 "	76 "	7 " 6 "
275 "	79 "	7 " 9 "
300 "	82 "	8 " 0 "
350 "	87 "	8 " 6 "
400 "	92 "	9 " 2 "
500 "	100 "	10 " 0 "

This table shows that the power of the steam-engine increases more rapidly than the area of the cylinder or the square of the diameter. By the rule of the square of the diameter, the power of an engine of 74 inches would be about 200 instead of about 225; and 100 inches diameter would give only 333 horse power; but the same rule would give too small a diameter for the lower powers. We believe that engines of the dimensions of this table will all work to more than their nominal power.

The best proportion between the diameter of the cylinder and the length of the stroke, has been the subject of much dispute, and of opposite practice. In America, a diameter of 40 inches is sometimes combined with a stroke of 10 or 11 feet, being more than double the length given in this country. On the Clyde, we have seen the opposite extreme, a diameter of 60 inches with a stroke of only 4 feet. For sea-going ships, the proportions we have given are the most convenient. In deviating from this proportion, a longer stroke will be preferable to a shorter; and with the necessary alterations required for high velocities of piston, a longer stroke working the steam expansively is likely to be attended with many advantages.

By means of a long stroke or great velocity of piston, considerable advantages are gained. The pressure upon the journals and working parts of the engine, and the consequent strain, is lessened in proportion to a given power. All the parts of the engine might be lighter than with a shorter stroke and a greater diameter of cylinder. A short stroke has however this advantage, that with a given length of lever and connecting rod, the angles of oblique pressure are smaller, and the intervals of time between maximum and minimum pressure are shorter. There are other peculiarities of smaller importance. On the whole, a longer stroke than that of the present British engine, as given in the table, is to be reckoned considerably preferable to a shorter one.

The velocity of the piston in the cylinder of a steam-engine is generally reckoned in this country at 220 feet a minute, and all the arrangements of the engine and its work are made on that principle. We can find no better reason for this than that a horse going at that speed, viz. two miles an hour, can draw 150 lbs. eight hours a-day, all the year round. Tredgold finds it to be a law of nature. It is strange how much this arbitrary dogma, transmitted without question, has retarded the improvement of steam navigation. It is a rule as universal in its acceptance as it is groundless and injurious. With large condensers, and large ports and valves, double the speed may be employed with great advantage.

The Condenser and Air-Pump.—The condenser is the most wonderful part of the marine-engine, as indeed of the ordinary steam-engine. It is here that the whole process carried on in the boiler in so great bulk, and at so much expense, is instantly reversed, and all its laborious effects at once, as it were, annihilated. It is the instantaneity of condensation that is its virtue: without this the whole of its virtue in the steam-engine is lost. Suppose a condenser capable of condensing the steam as fast as it is generated by the boiler, and given off in the cylinder, and no faster, what would be the consequence? The power of the engine would cease, the elastic force of the steam above the atmosphere would alone act, the steam being only condensed as the piston carried it out of the cylinder; the engine would become nothing else in power but a high-pressure engine, whose steam is merely condensed before going out into the atmosphere. It is by forming a perfect vacuum in the

Steam Na-
vigation.

Cylinder
of the
Marine
Engine.

Length o.
stroke.

Condenser
and air-
pump of
Marine
Engines.

Steam Na- cylinder on the moment when the steam is about to
vigation. enter on the opposite side, that the full power of the
steam can alone be obtained in useful effect. A perfect
condenser must, therefore, have much greater capability
than that of merely condensing the steam as fast as the
boiler is capable of evacuating it, or the engine of
passing it through.

Attempts to effect condensation without injection water. We have insisted the more strongly on this point,
inasmuch as it is here principally that power is to be
gained at smallest expense. Many other modes of con-
densation have been tried besides condensation by jet,
and without effect. Newcomen tried to condense by
cold water outside his condenser; so did Savary, so did
Watt, so did Cartwright, so did Napier on the Clyde,
so did Stevens of Hoboken in America, so did Trevi-
thick, Symington, Mills, and many others; but without
success: for though they all succeeded so far as, by hav-
ing cold water on the outside of the vessels, to condense
the steam in the inside, yet this condensation by con-
tact, however perfect in quantity, has always been
slower in time than condensation by jet, and has conse-
quently failed in developing the full power of the engine.
In this list we have not mentioned the name of the
ingenious and enterprising Mr Hall of Basford, as he
still continues to persevere against the difficulty of in-
troducing successfully into use the system which has baf-
fled the efforts of his predecessors; and perhaps his
attempt may be attended with a higher degree of suc-
cess than theirs.

Size of the condenser. It appears difficult to assign a volume to the con-
denser which shall give it most efficiency. We have
seen efficient condensers from one-fourth of the volume
of the cylinder up to its full size. One-half the volume
of the cylinder appears to be a size sufficiently con-
venient and effective.

Various modes in which the injection water may be distributed in the condenser. The proper distribution of the water forming the jet,
throughout the whole volume of the condenser, seems
the most important point of efficacy in the condenser.
Some engineers accomplish this by allowing the water
to rise from the bottom of the condenser in a *jet d'eau*,
which striking the top, falls down in a shower, filling
the whole condenser; others make this shower radiate
in all directions from a perforated horizontal pipe; and
a third most effective method is, to spread out the jet
in a thin film or sheet, like a waterfall, through which
the steam is compelled to pass. In marine engines, the
water is permitted to flow into the condenser through
a pipe in the ship's side, regulated by a cock.

Vacuum in the con- denser may be too good. Much has been said regarding the perfection of the
vacuum found in the condenser of a steam-engine, espe-
cially a marine engine. It does not appear to be known
that a vacuum may be too good. We hear it boasted
every day by rival engineers that their engines have the
best vacuum. Some boast their vacuum at 27 inches,
others at 28, others at 29, some at 30, and at last an
engineer appears who boasts a vacuum of 30½ inches.
It is to be regretted that time and talent should be thus
wasted. It is a fact of great importance, confirmed by
experiment and by practice, that a vacuum may be too
good, and become a loss instead of a gain. The truth
is simply this, and should be known to every engineer:
*If the barometer stand at 29½ inches, the standard of this
country, the vacuum in the condenser is too good
if it raise in the barometer more than 28 inches of mer-
cury.* This important truth is incontrovertible, and is
practically exhibited every day.

The following is a simple proof of this doctrine, di-
vested as far as possible of a technical form, and put in
the shape of an enquiry into the best state of a con-
denser.

VOL. XX.

Let t = the caloric of water of 1°.

c = the constituent caloric of water in the state
of steam.

e = the total force of steam in the boiler in inches
of mercury;

and x = the elastic force of steam at the temperature
of best condensation which we seek to dis-
cover.

Then from the law which connects the elastic force of
steam with temperature, as already determined in the
article STEAM, it follows, that in the case of maximum
effect, or the temperature of best condensation,

$$\frac{t}{c} = \frac{x}{e} \text{ that is } x = \frac{et}{c}$$

now $c = 1000$, and if the steam in the boiler be at 5 lbs.
above the atmosphere, or if $e = 40$ inches of mercury,
and $t = 1$,

$$x = \frac{40}{1000} = 0.04$$

Again, if the steam be at 7½ lbs. = 45 inches,

$$x = \frac{45}{1000} = 0.045$$

Again, if the steam be at 10 lbs. = 50 inches,

$$x = \frac{50}{1000} = 0.05$$

Hence, we find that the best elasticity or temperature
in the condenser depends on the elastic force of the
steam in the boiler.

With steam of 5 lbs. in the boiler, the elasticity of
maximum effect in the condenser is at 93° of Fahrenheit,
and the best vacuum in the barometer is 28. With
steam of 7½ lbs. in the boiler, the elasticity of maximum
effect in the condenser is 95° of Fahrenheit, and the
best vacuum in the barometer is 27.8. With steam of 10
lbs. in the boiler, the elasticity of maximum effect in
the condenser is 97°, and the best vacuum in the baro-
meter is 27.5. In like manner it would be found that
with steam of 50 lbs. in the boiler, worked expansively,
as in Cornwall, the best vacuum in the condenser would
be about 26° on the barometer.

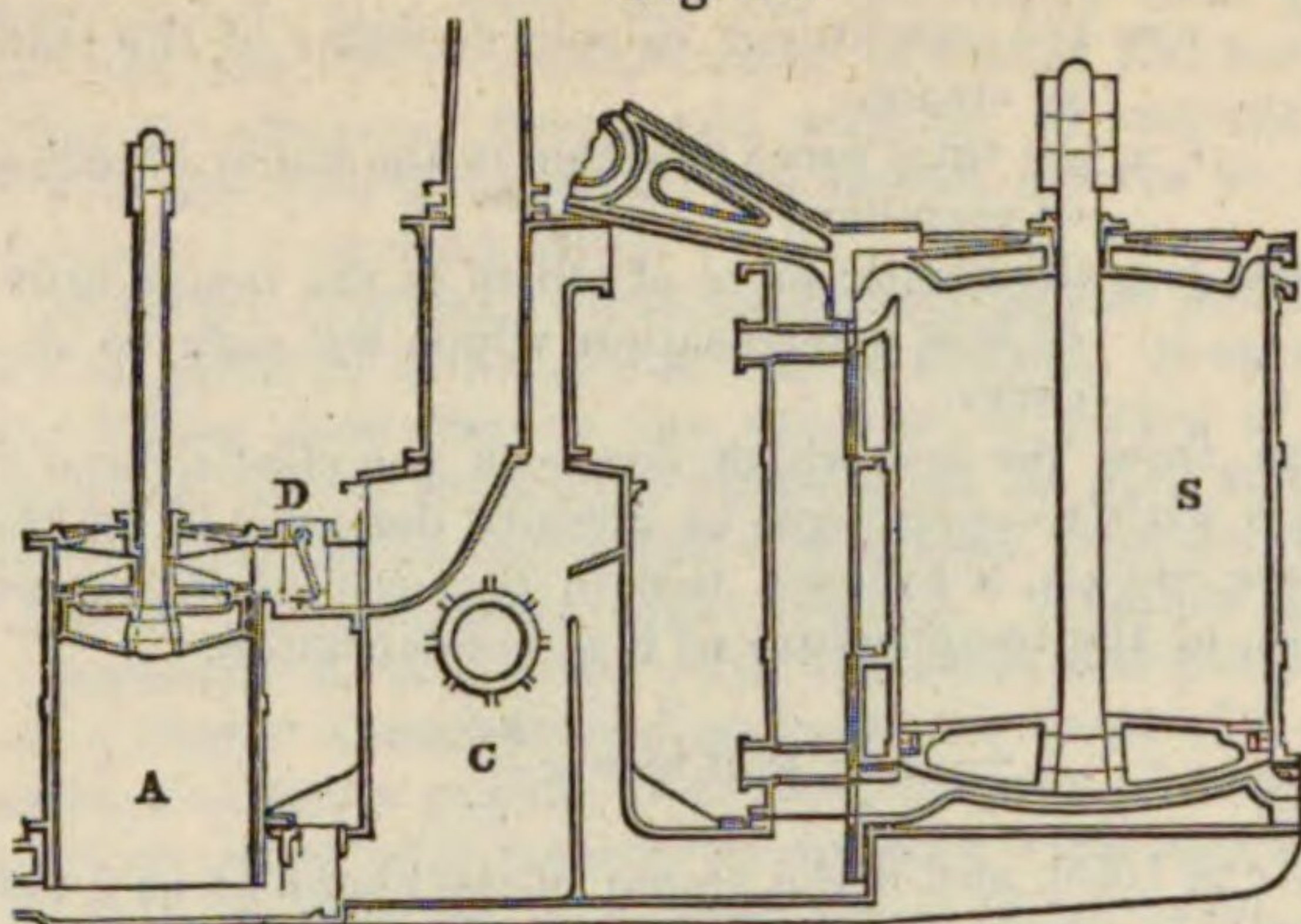
It is hoped, therefore, that engineers will not in fu-
ture distress themselves, at finding the vacuum of their
condenser much less perfect than the vacuum of others
who have obtained 30, and 30½ inches, at so great a loss
of fuel and power. To obtain a vacuum of 29½ with
the weather-glass at 29.75, and steam at 7½ lbs., would
be to sacrifice four horse power out of every hundred.
In a day when the barometer is as low as 28½ inches,
the vacuum in the condenser should indicate 26.8.

In speaking of the vacuum in the condenser, it would
save much ambiguity to indicate the elasticity merely of
the gas in the condenser. Thus, if the barometer stands
without at 29½, and the barometer of the condenser at 28,
it might be stated that the steam in the condenser stands at
1½, being the point of maximum effect; and the indication
would at all times convey more precise information.

An air-pump is an appendage rendered necessary by Air-pump
the condenser, and especially by condensation by *jet* of marine
d'eau. Ordinary water contains about 5 per cent. of engines.
air and other gases, which become disengaged in the
condenser, and must be withdrawn, to maintain the
vacuum. Hence the air-pump, which is also used to
withdraw the water which accumulates in the conden-
ser. A valve between it and the condenser is called
the foot valve; and a valve at the exit from the top of
the air-pump is called the discharge valve. They are
thus arranged: S the cylinder, C the condenser, A the
air-pump, F the foot valve, and D the discharge valve.

Steam Na-
vigation.

Fig. 19.



The dimensions of the air-pump seem to vary much, from $\frac{1}{8}$ to $\frac{1}{2}$ of the volume of the steam-cylinder. I do not know any disadvantage of importance in having a large air-pump; as, if properly constructed, the force which is required to work it will be nearly in the proportion of the elasticity of the gas which it has to remove from the condenser. To give the air-pump half the stroke of the cylinder and $\frac{1}{3}$ of the area of the cylinder, or $\frac{1}{3}$ of the stroke of the cylinder and $\frac{1}{2}$ the area of the cylinder, are common proportions.

Area of the
valves and
valve pas-
sages.

The Valves and Valve Passages.—The notion that because a horse can do most work at the rate of $2\frac{1}{4}$ miles an hour, or 220 feet a minute, therefore a steam-engine should also move at that rate, is a prescriptive error almost ridiculous; but from which it will nevertheless be difficult for us to escape, especially as the proportions generally in use are derived from this absurd dogma. There is no doubt that the passages and valves should simply be as large as possible, and those valves should be used which can be most enlarged with least inconvenience. Such valves we possess in the class of equilibrium valves. These valves may have an area as large as the tenth-part of the cylinder without disadvantage, and the velocity of the piston may thus be increased, and consequently the power of the engine, with great advantage, especially in steam navigation. We have the best possible means of knowing, that with proper valves and passages, the speed of the piston may very advantageously be increased to 250, 300, 400, and 500 feet a minute. The pistons of the swiftest vessels in the world move at that rate.

Various
kinds of
valves used
in marine
engines.

The kind of valve most commonly in use in steam-vessels is the long D-slide, as it is called; and next to that is the short D-slide. There are scarcely any other kinds in use in Britain. A valve called the four-port slide valve has been used to a limited extent, as have also conical valves, and equilibrium valves, or double heat valves in this country, the latter very extensively in America. The following are diagrams of the long and short D-slides.

Fig. 20.

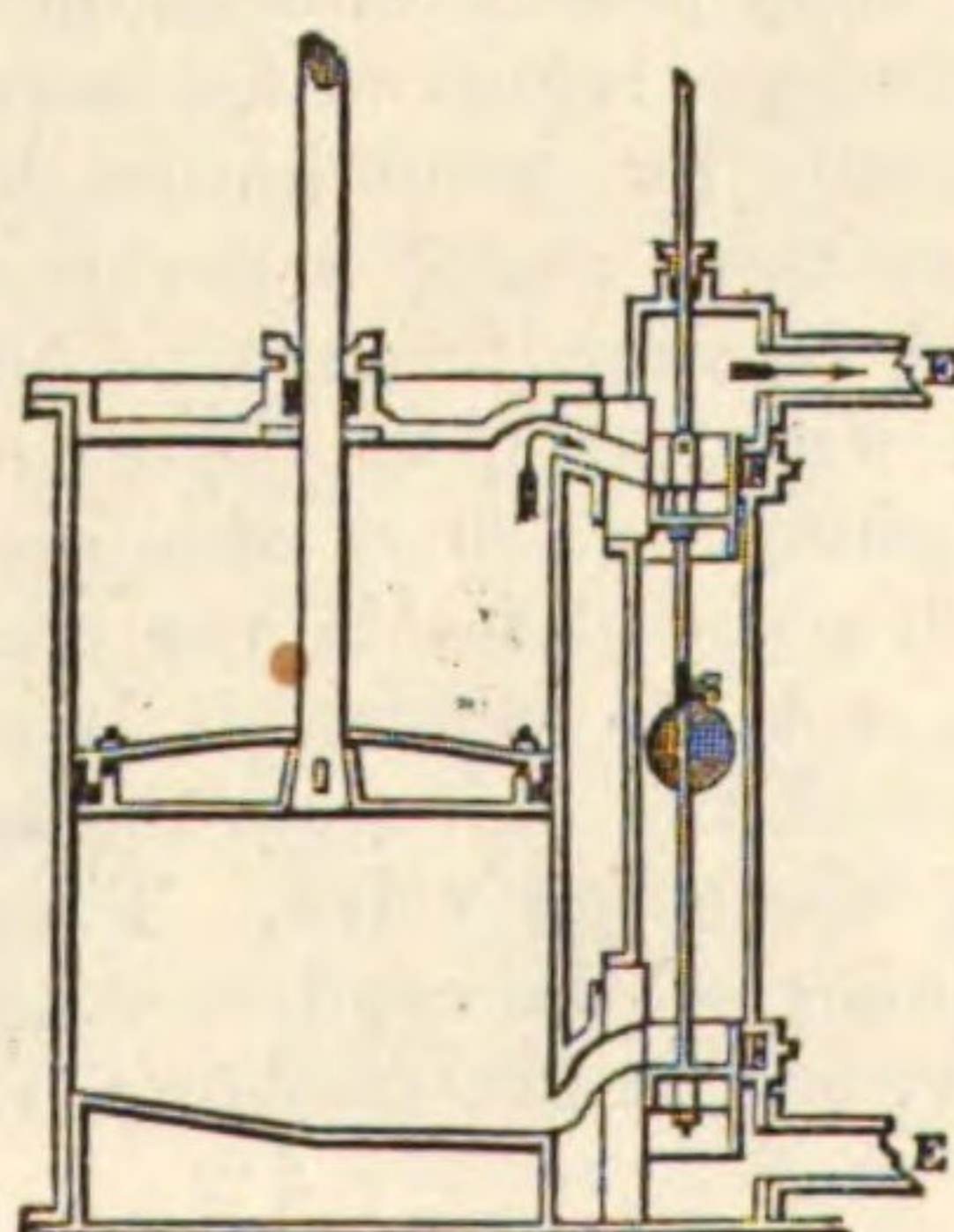
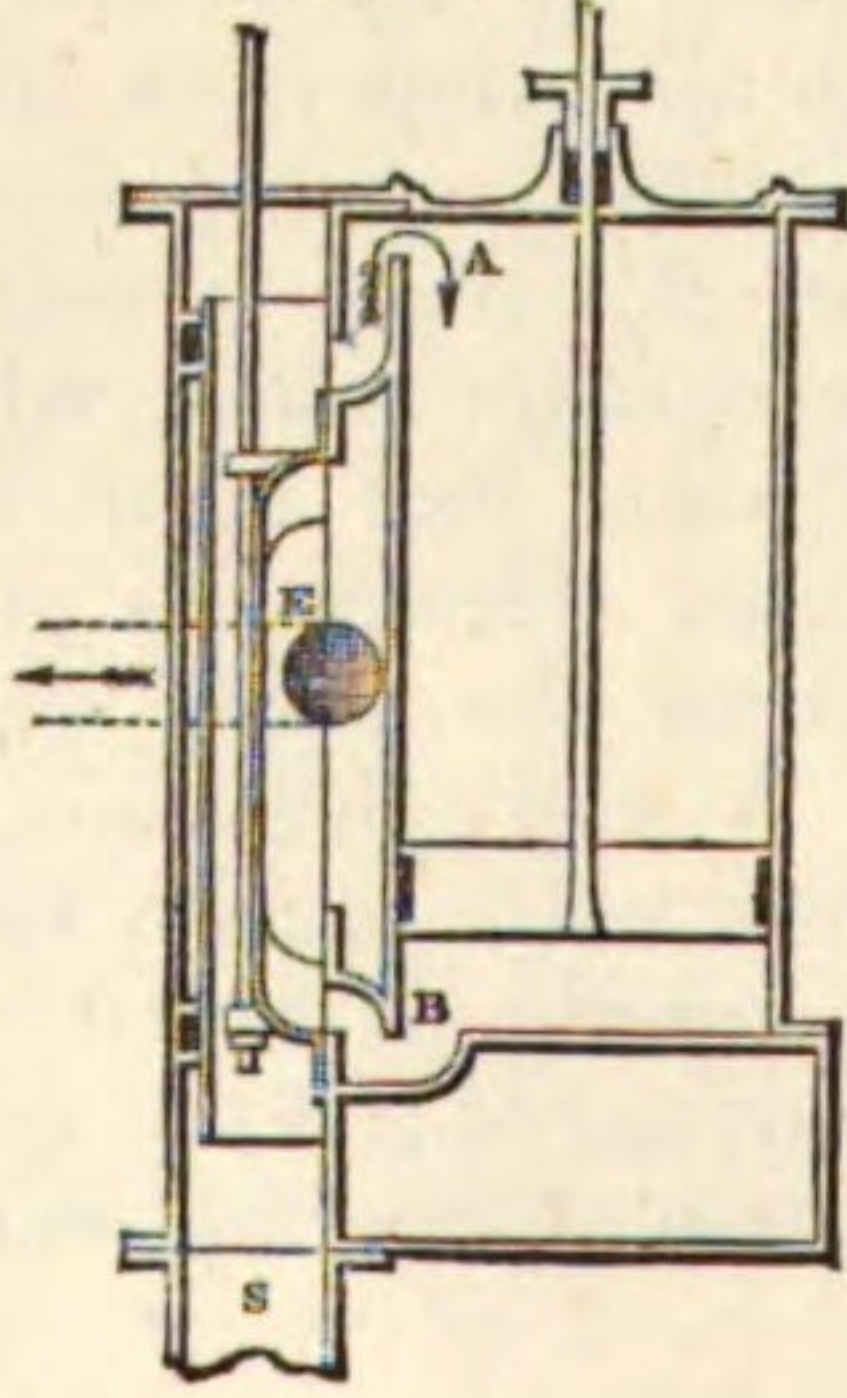
The D-
slide valve.

Fig. 21.



The four-port slide valve is a recent invention, having been the subject of a patent so lately as 1833. Since that time they have been used to a considerable extent in one part of Scotland. The same kind of valve was subsequently patented by another party in England, and these valves were put on board of some of her Majesty's frigates. The following figures represent the four-port slide valve, in two positions. A the cylinder; pp the piston; S the steam-pipe; VVVV the slide valves. The arrows show the direction of the steam.

Fig. 22.

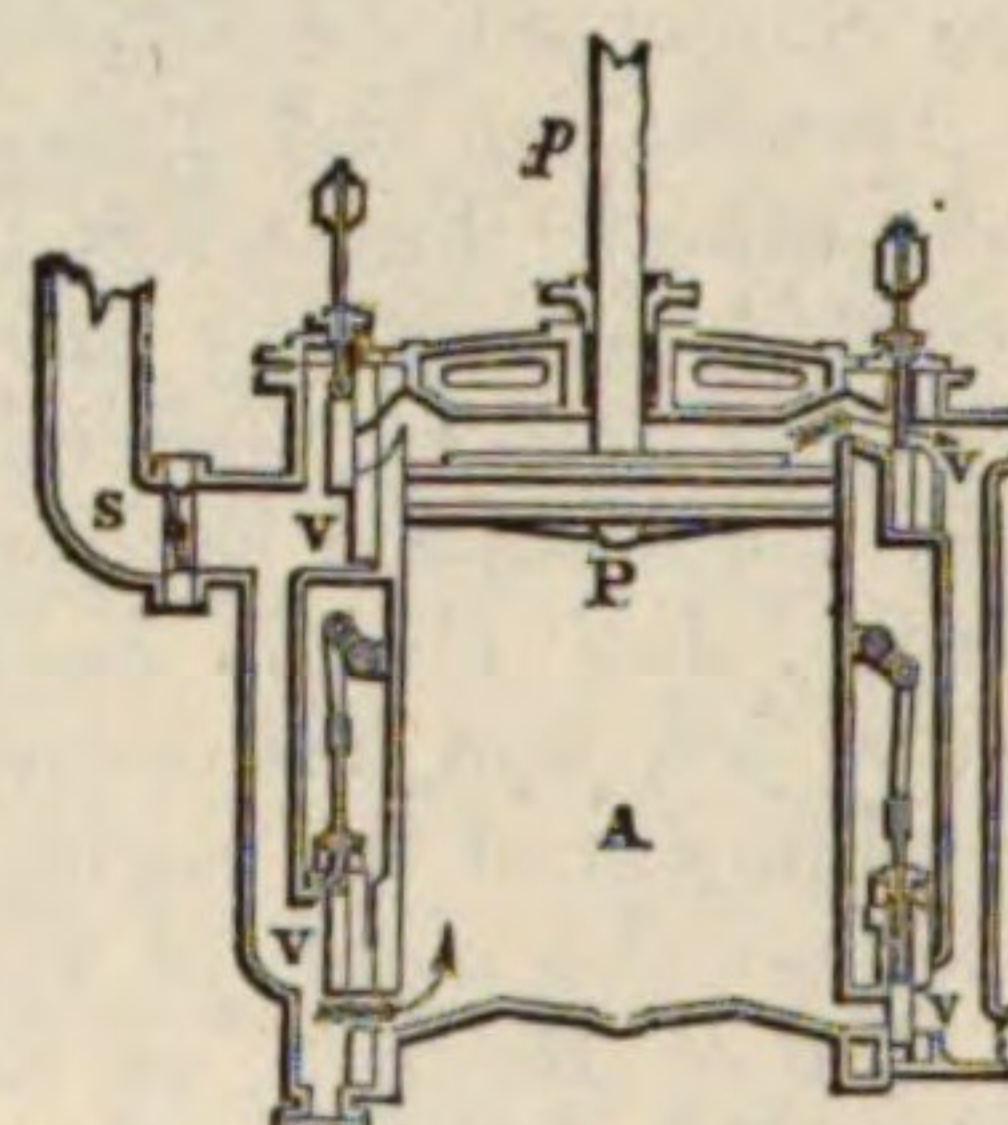
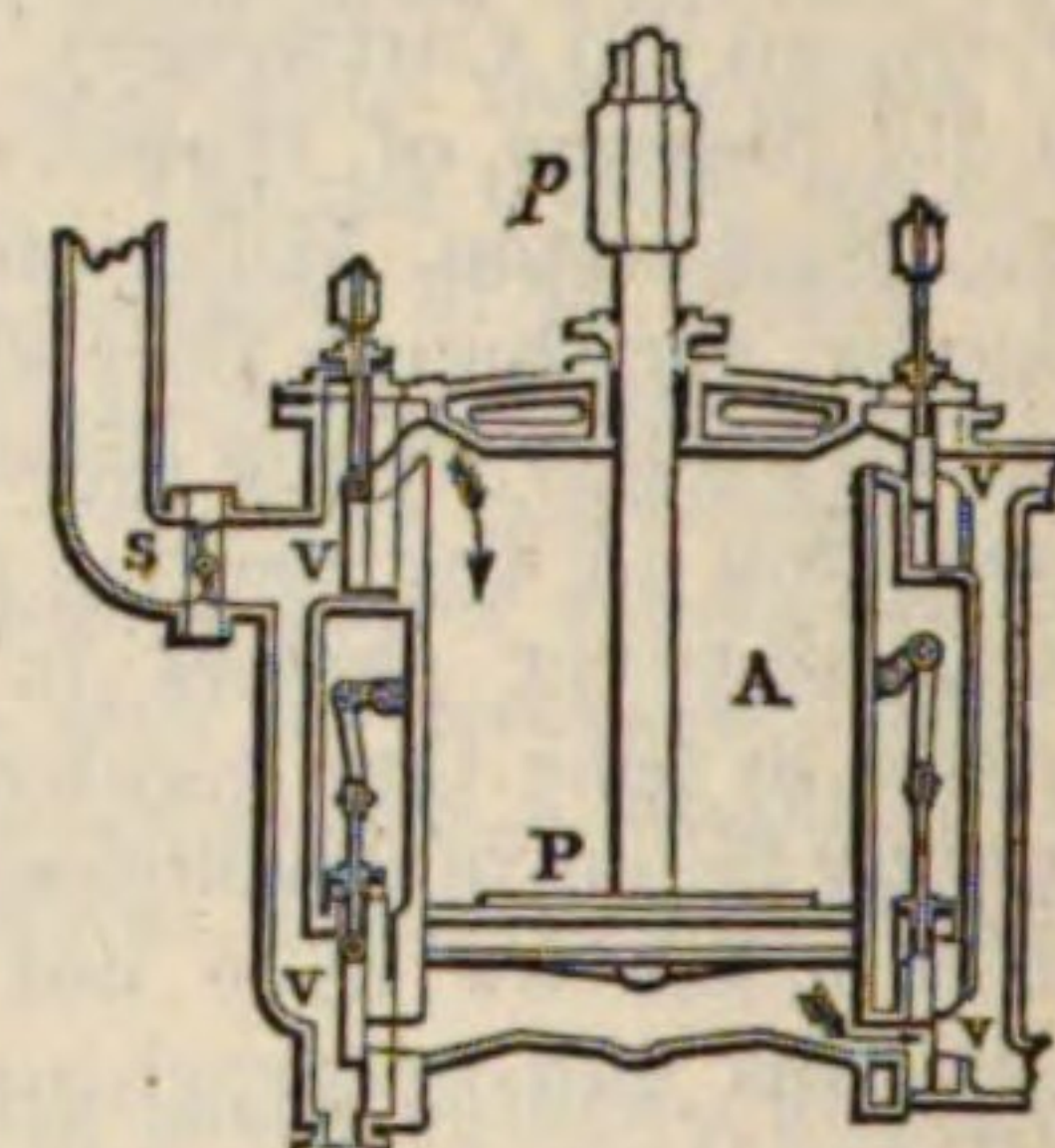


Fig. 23.



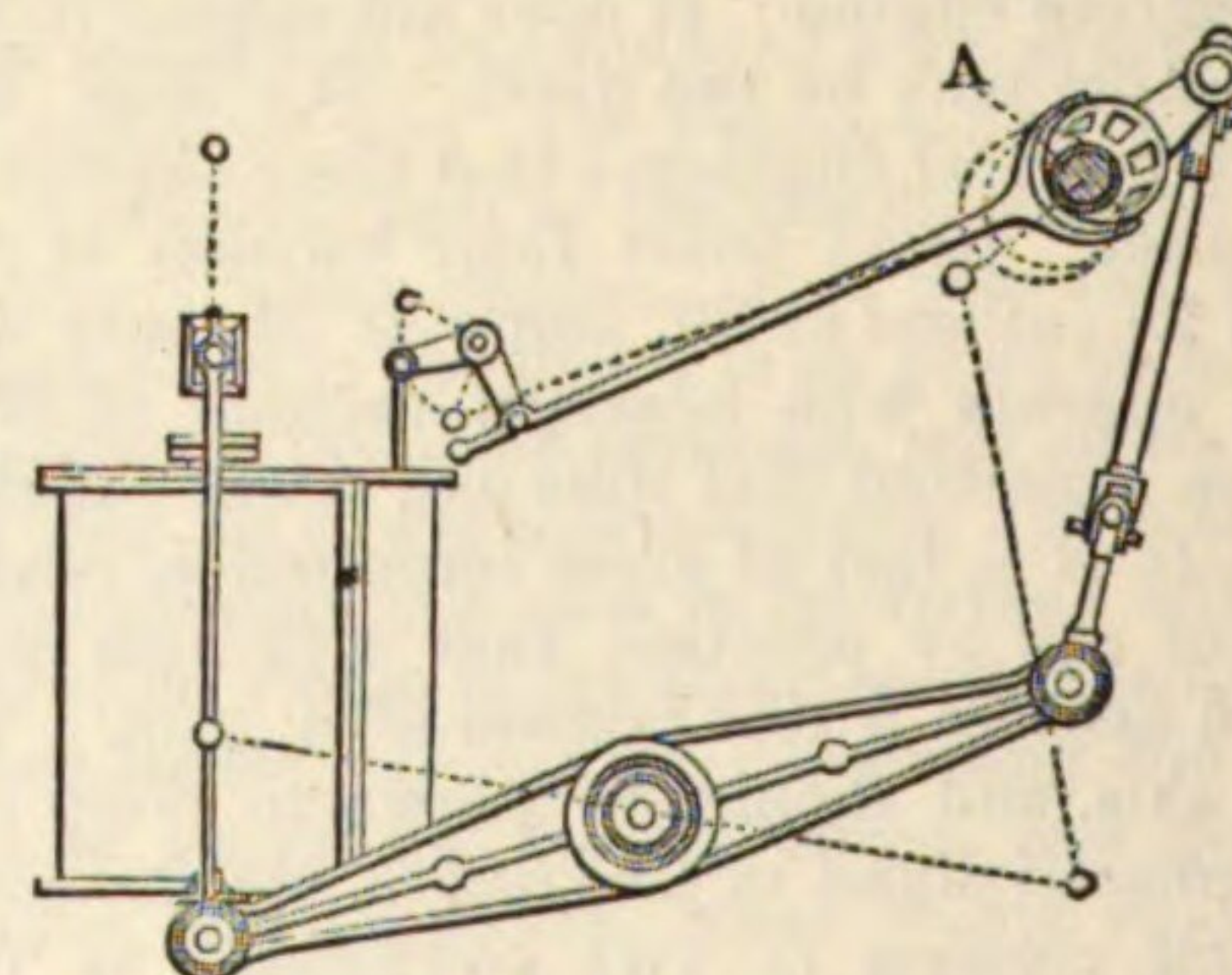
The equilibrium valve has already been described in the article STEAM-ENGINE.

The size of the valves is a matter of some consequence. That the valves, passages, and ports by which the steam enters the cylinder should allow a free passage of $\frac{1}{25}$ of the area of the cylinder, is an old and pretty general rule. It is equally certain, however, that the eduction valves, ports, and passages by which the steam enters the condenser should be much larger. They have been made $\frac{1}{12}$ th and $\frac{1}{10}$ th of the area of the cylinder with advantage, in the case of high velocity of the piston.

The Eccentric.—The valves, by means of which the steam is alternately admitted to the cylinder on one side, and educted from the other side, into the condenser, are moved by the machine itself; and the very simple and beautiful automatic contrivance for that purpose is called the eccentric.

We have already described the actions of the eccentric in the article STEAM-ENGINE. In the marine engine it is placed on the axis of the paddle wheels. In fig. 24 its usual arrangement is shown, and in the Plates many examples will be found.

Fig. 24.



As the shaft A moves round, it is plain that the projection of the eccentric, first on one side of the shaft and then on the other side, will draw the eccentric rod in opposite directions; and the distance of the centre of the eccentric from the centre of the shaft, will be placed now on one side and now on another side of the axis. The motion thus produced is called the throw of the eccentric; and half the throw is equal to the eccentricity.

Steam Na-
vigation.

The lead of
the valves.

An important point in setting the valves is what is called the lead on the centres. What is the best instant of time at which to allow the steam to enter or escape from the cylinder? At first sight we should say, precisely at the instant of reversing the direction of the motion. This is not the case. Great advantage is gained by letting the steam out of the condenser before the end of the stroke. A little of the force of the steam in the cylinder may thus be sacrificed; but it is a very little, say $\frac{1}{50}$ th of the stroke, and is much more than compensated by this, that the steam escaping thus early into the condenser, time is allowed for effectual condensation, and there is an excellent vacuum in the cylinder by the time when the back-stroke begins. In like manner, the steam-port may be slightly opened before the engine comes to the centre; and as there are vacuities at the top of the cylinders to be filled, and as time is wanting for the passage of the steam, this is allowed. By the same means also the steam is cut off a little before coming to the end of the stroke, which allows the engine to work expansively; and the vacuum port may in like manner be shut, as the vapour will have been perfectly condensed in the cylinder long before the end of the stroke. Much of the efficiency of an engine depends on the adjustment of the slide.

Eccentric
in marine
engines
generally
loose on
the shaft.

The eccentric of the marine engine is generally a loose eccentric, capable of turning the valves either so as to give the engine motion forwards or backwards. By placing the eccentric loose upon the axis, only with a projection on one side, which is carried round by a corresponding projection on the axis, it is left free, except when this check comes in contact with the projection at either end of the stroke. To effect this, it is necessary to open the valves by hand through at least one half-stroke.

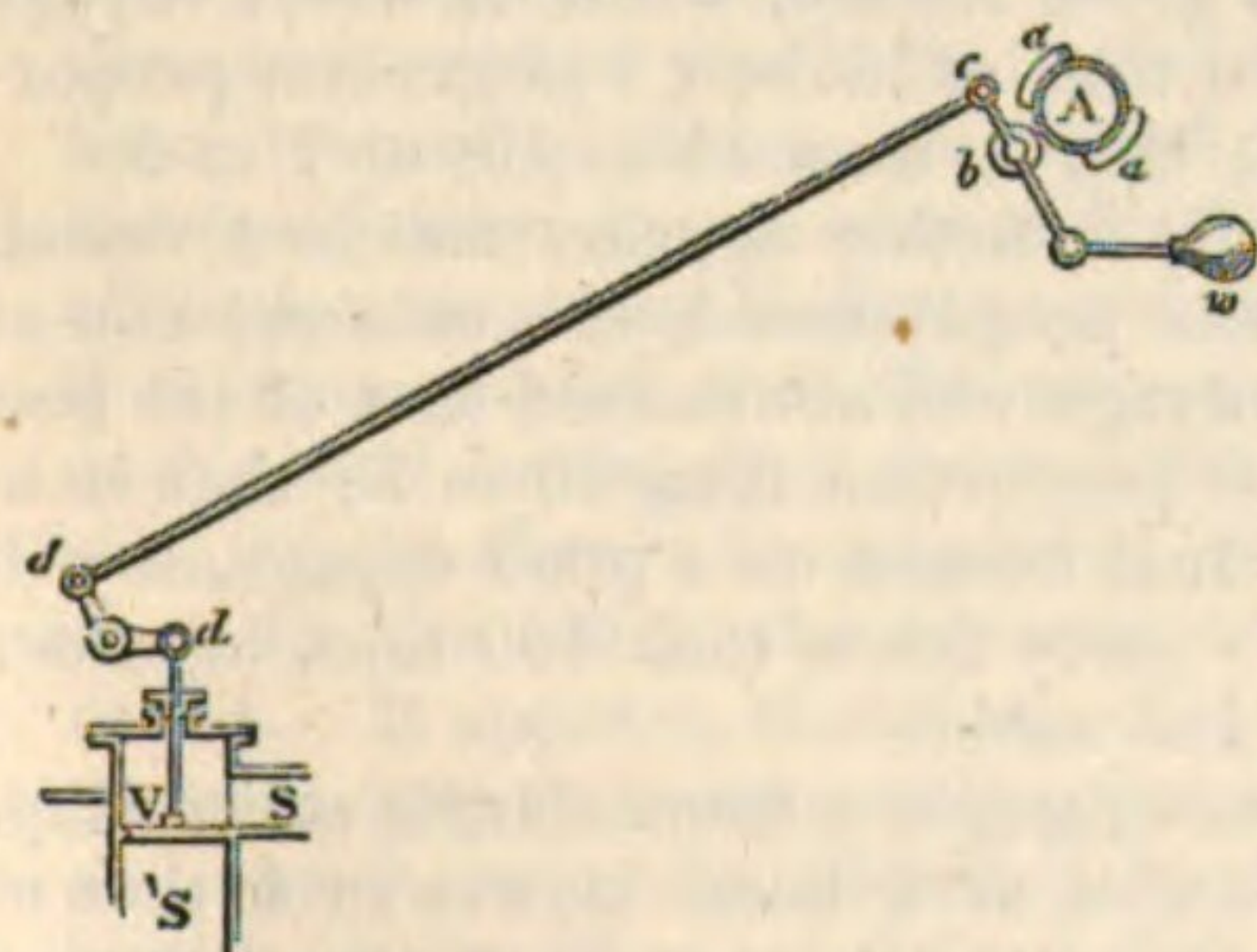
Hand-
Gear.

The Hand-Gear.—The hand-gear is generally a lever or series of levers, which enables the engineer to shut and open the valves by hand before placing them in connexion with the eccentric. By this means he places the machine either in the condition to keep moving forwards or backwards. For examples see the Plates.

Expansive
Valves.

The Expansive Valves.—It is of advantage to cut off a part of the steam which would be required to fill the cylinder, so as to allow that quantity which has partly filled it to expand with its elastic force, and fill the rest of the cylinder without further supply from the boiler. The advantage of doing this, especially in long voyages, has now become pretty generally known. A stop-

Fig. 25.



valve V, fig. 25, is placed on the steam-pipe S S', before it joins the casing of the common valves, which are applied as usual. The principal axis A of the engine carries a cam, with two projections *a a* proportioned in breadth to the extent of the stroke which is cut off. On this cam rolls a small pulley *b*, pressed close by a weight *w*; and by a simple connecting rod the cam opens and shuts the valve with great velocity twice in each revolution. On this cam there may be various grades at which the steam may be cut off in the stroke of the engine. This apparatus is used in all vessels calculated for long voyages.

The Proportion of Power to Tonnage.—Large power

or small power has always been one of the *veraxæ question*es of steam navigation. The early steam-boat engines had but a small power proportioned to the tonnage of the vessels in which they were placed. The Comet had 25 tons burden and only three horse power; being about one horse power to eight tons, or a proportion of power to tonnage amounting to one-eighth.

On this subject modern practice and modern opinion seem to offer no guide. A low proportion of power and a high proportion of power have both their advocates. The East India Company have advocated and used low proportions of power to tonnage, and in this they appear to have followed the general maxims of southern engineers. The Government also appears to have adopted the same course; but without going to the same extreme. The Clyde engineers adopt the opposite maxim, and place as much power in their vessels as can be conveniently applied. There appears at the present moment to be a strong feeling in favour of a high proportion of power to tonnage. It has been found by some of the best mercantile companies, that a high proportion is not only better for expedition, but also more economical of fuel and of capital than a smaller proportion; and instances are frequent of an increase in the power of a steam-vessel, producing a diminution in the consumption of fuel.

As this question is becoming every day of greater importance, it is proper to examine it carefully. In the first place, it is well known that the proportion of power must be very much increased to gain a given increase of speed. Thus, if 120 horse power propel a vessel through water five miles an hour, it will require forty horse-power to propel the same vessel ten miles an hour, or it will require a quadruple power to obtain a double speed; and, in like manner, it will require a ninefold power to triple the speed. In fact, the increased speed requires an increased power in a duplicate ratio of the increased speed; or if the speeds be as the numbers 1, 2, 3, 4, 5, 9, 10, &c., the power required to attain those speeds must be 1, 4, 9, 15, 25, 81, 100 horses; or according to the well known law of the resistance of fluids, the resistance which the water opposes to increased speed is nearly in the duplicate proportion of the speed. Thus, to increase the speed in a given proportion, the fire of the engine and the consumption of fuel, which is nearly as the power of the engine, must be increased in a very high proportion. Hence the seeming great economy of a low power of engine and a small consumption of fuel.

Thus a large power of engine occupies much of the useful space of the vessel, which might have been filled with cargo. It consumes much coal, and the speed is by no means proportioned to the expense of fuel and machinery. But this is a very limited view of the subject. If time as an element, and a very important one in the value of mercantile conveyance, be calculated, then it will in many cases be found, that high speed at any expense of fuel will compensate for that expense. This is the case to a great extent in Britain, and especially in America, where a quarter of a mile an hour between the speed of two vessels ruins the fortune of one owner, and makes the fortune of another. But it is not on the value of speed at the present day, that we proceed in this enquiry; that can at once be appreciated by the local peculiarities of a given case. We are to enquire what may be the best proportion of power to tonnage in sea-going vessels, apart from the mere price of speed in the market.

We have seen that the lowest speed in a steam-vessel is the most economical, and that it requires great and expensive additions of power to gain high velocities.

Steam Na-
vigation.

Proportion
of
power to
tonnage.

Steam Na-
vigation.

Proportion of
power to
tonnage in
steam-
vessels.

But in arriving at this conclusion, we have taken only the case of smooth and still water. Here it is obvious that the slowest rate and smallest power will be most economical; but it should be remembered that the great purposes of steam are generally of a different nature from the mere generation of motion through a quiescent fluid. The force of adverse winds and waves is to be opposed, stream-tides and currents are to be stemmed; and it is the success of steam in conquering those obstacles, and obtaining regularity and speed in spite of them, which constitutes its superiority over wind or animal power in navigation.

Now, if we take a simple case of one of these, we shall soon find that a higher proportion of power to tonnage may be essential, not only to speed, but even to economy. Suppose a steam-boat with a small proportion of power, capable of propelling the vessel at the velocity of three miles an hour through still water, to be applied to stem a current of three miles an hour, is it not plain that the vessel would make no head way, and thus a low proportion of power would burn an immense quantity of coal in doing nothing but standing still?

Let us again suppose that the same vessel, capable of steaming three miles an hour, meets with a moderately strong breeze opposed to her, such as prevents her from making any progress at all against it; then it is plain that by the continuation of this breeze, the vessel burning a continual supply of fuel would consume an indefinite quantity of coal in standing still. This extreme case of too little power, shows that there is at least one proportion of power, which is too small for economy of fuel; viz., that proportion which, being very economical of fuel in fine weather, is brought up altogether by adverse winds. In this case, the consumption of fuel is rendered indefinite, and the useful effect of fuel completely annihilated by too small a proportion of power.

As, then, we have plainly established the existence of a limit to diminution of power, in the vicinity of which it must be followed by extravagant consumption of fuel, we may now proceed to investigate the question of best proportion, or the point where the attainment of high speed is accompanied by absolute saving of fuel as compared to lower velocity. For this purpose, we merely take it for granted that the speed through the water will be nearly as the square root of the power, according to the general law of the resistance of fluids; that the resistance offered by bad weather or adverse winds has been ascertained and is determined on a particular station: that is, that it is known that on a given station a given vessel with a given power makes a voyage in adverse circumstances in, suppose, double the time of her most prosperous voyage; say her most prosperous voyage is in fourteen days, and her adverse voyage in twenty-four days, being a retarding power of ten days out of twenty-four; we take this retardation of ten days as the measure of the retarding power of adverse weather in the given circumstances. And further, let the following quantities be thus represented:—

Let h be the power, v the velocity, f the fuel consumed, t the time in good weather,	In a given vessel, on a given station.
Let h' be the power, v' the velocity, f' the fuel consumed, t' the time in bad weather,	
Let h'' be the power, v'' the velocity, f'' the fuel consumed, t'' the time in good weather,	In another vessel of greater power on the same station.
Let h''' be the power, v''' the velocity, f''' the fuel consumed, t''' the time in bad weather,	

Also, let k represent the consumption of fuel per horse-power per hour, and s the length of the voyage or distance performed. Then

$$f = k h \frac{s}{v}$$

$$f' = k h' \frac{s}{v'}$$

$$f'' = k h' \frac{s}{v''}$$

$$f''' = k h' \frac{s}{v'''}$$

v = a given quantity,

v' = a given quantity.

and

$$v'' = v \frac{h' \frac{1}{2}}{h \frac{1}{2}}$$

$$v''' = \left\{ \left(\frac{h' \frac{1}{2}}{h \frac{1}{2}} \right)^2 - v^2 + v'^2 \right\}^{\frac{1}{2}}$$

$$\text{hence } f''' = \frac{k h' s}{v'''} = k h' s \left\{ \left(\frac{h' \frac{1}{2}}{h \frac{1}{2}} \right)^2 - v^2 + v'^2 \right\}^{-\frac{1}{2}}$$

Putting $f''' = u$, $h' = x$, and differentiating, we get

$$\frac{du}{dx} = \left(v^2 \frac{h'}{h} - v^2 + v'^2 \right) - \frac{1}{2} v^2 \frac{h'}{h} \left(v^2 \frac{h'}{h} - v^2 + v'^2 \right)^{-\frac{3}{2}}$$

whence by reduction, in the case of a minimum, we obtain the value

$$x \ 2 h = \frac{v^2 - v'^2}{v^2} \dots \dots \dots (A.)$$

Whence we obtain the very simple rule for finding the best proportion of power to tonnage: *From the square of the velocity of any given vessel in good weather, subtract the square of the velocity of the same vessel in the worst weather, divide the difference by the square of the velocity in good weather, and the quotient multiplied into double the horse-power of the said vessel will give the power which would propel the same vessel in the same circumstances with the smallest quantity of fuel.*

We have also from (A) $h' = 2 h \frac{v^2 - v'^2}{v^2}$

$$(B) v'' = \sqrt{2} (v^2 - v'^2)^{\frac{1}{2}}$$

$$(C) v''' = (v^2 - v'^2)^{\frac{1}{2}}$$

$$(D) f'' = \sqrt{2} \frac{k h s}{v^2} (v^2 - v'^2)^{\frac{1}{2}}$$

$$(E) f''' = \frac{2 k h s}{v^2} (v^2 - v'^2)^{\frac{1}{2}}$$

$$(F) t'' = \frac{s}{\sqrt{2} (v^2 - v'^2)}$$

$$(G) t''' = \frac{s}{\sqrt{v^2 - v'^2}}$$

It appears from the comparison of (B) with (C), that a vessel has its power in the most economical proportion to its tonnage on a given station, when its worst voyage does not exceed the time of its best in a greater proportion than $\sqrt{2}$ to 1; that is, than 14 to 10, or 7 to 5.

From (D) and (E) it further appears that in a vessel, whose power is thus proportioned, the consumption of fuel in the worst voyage will not exceed that of the best voyage in a greater proportion than 10 to 7; that is to say, for 70 tons of fuel burned on a good voyage, it will not be necessary to carry more than 100 tons, in order to provide against the worst.

Let us take as an example a transatlantic steam-ship, which has a proportion of 1 horse power to 4 tons of capacity. Her unfavourable voyage being between England and America twenty-two days, and her favourable voyage fourteen days, being a comparative velocity of 7 and 11, then

$$h' = 2 h \frac{v^2 - v'^2}{v^2} = 2 \cdot \frac{121 - 49}{121} = 2 \cdot \frac{72}{121} = \frac{12}{10} \text{ nearly.}$$

Hence, the power of such a vessel should be increased in the ratio of six to five; that is to say, the engines at

Steam Na-
vigation.

Proportion of power to tonnage in steam-vessels.

Steam Navigation. present capable of exerting a power of 500 horses, should have been capable of exerting a power of 600 horses, and would in this case have consumed less fuel, as well as have produced greater regularity and a higher velocity.

Proportion of power to tonnage in steam-vessels. The following results are obtained:—

The vessel of less power burns thirty tons per day, performs the distance in fourteen days, consuming 420 tons of coals in fair weather.

The vessel of less power burns thirty tons per day, performs the distance in twenty-two days, consuming 660 tons of coals, in foul weather.

The vessel of greater power burns thirty-six tons per day, performs the distance in twelve and one-half days, consuming 468 tons of coals, in fair weather.

The vessel of greater power burns thirty-six tons per day, performs the distance in seventeen days, consuming 630 tons of coals, in foul weather; being a consumption of sixty-four tons less fuel, and performing the voyage in four and a half days less than the other.

It is manifest that the store of fuel carried in the vessel with less power, must on all occasions be equal to the greatest consumption of fuel, that is, to at least 660 tons, whereas 630 tons will be sufficient for the vessel of greater power; and as in all vessels for long voyages, coals carried are much more costly than the mere price of coals, or as the freight of the vessel is more costly than the fuel, coals carried are to be reckoned at least as expensive as coals burned. Moreover, as the gain in time and in capital is four one-half out of twenty-two, being twenty-five per cent, it is plain that the vessel may be calculated to perform the distance oftener in a year; because as the times of starting must always be regulated, not by the shorter but by the longest period of a voyage, seventeen one-half days in the one case, stand in the place of twenty-two days in the other.

As another example, let us take the case of a vessel calculated to stem the monsoon in the Indian seas. A vessel of 600 tons and 200 horse power, steaming in fair weather at the rate of eleven miles an hour, has been found to have her speed diminished by the monsoon to five miles an hour. What would be the best proportion of power in such circumstances?

$$h' = 2h \frac{v^2 - v'^2}{v^2} = 2 \frac{11^2 - 5^2}{11^2} = \frac{16}{10} \text{ nearly.}$$

Hence we see that the power being increased in the ratio of sixteen to ten, that is, engines of 320 horse-power being substituted for those of 200, the speed on the quick voyage would be twelve three-fourth miles an hour, instead of eleven, the speed against the monsoon increased from five to nine miles an hour, with a saving of coals amounting to forty tons out of 320; and when it is remembered that the voyage for which eighteen days would be required as continual allowance in the one case, might always be calculated on as performed in ten days in the other, the advantage is placed beyond all doubt. It appears, therefore, that for long voyages especially, great advantages in point of economy, certainty, and speed, are to be obtained by the use of vessels of a higher power than usual; and that, in a given case, the best proportion of power to tonnage may readily be determined from the rules already given.

In regard to absolute or definite proportion, it may be stated as the result of the best vessels, that the proportion of power to tonnage should not be greater than one horse power to two tons; the greater proportion holding in the smaller, and the less proportion of power in the greater vessel.

The Proportions, Form, and Mechanical Structure of Steam-Ships.—In the article SHIPBUILDING, the reader

will find the elements of construction of ships developed and applied in a satisfactory and lucid manner. There he will also learn, that naval architecture is scarcely recognised as a science in England. The reader will therefore be prepared for the announcement that the proportions and structure of steam-vessels is an enquiry which has hardly as yet systematically commenced; and it is with much hesitation that we set the example of endeavouring to eliminate from the rude mass of practical truth and practical error, some general results worthy of confidence. We may premise, that the drawing and finding the displacement, centres of gravity, and buoyancy, and the calculations of stability, &c., may be performed for steam-ships by the methods, and on the principles developed in the article to which the reader has already been referred.

The proportions of steam-vessels were originally taken from sailing vessels; the length being three or four times the breadth. Six breadths to the length is now a common proportion. The proportion of depth varies with dimension, being about one-half the breadth in vessels of 100 tons, two-thirds of the breadth in vessels of about 600 tons, and three-fourths of the breadth in vessels of 1500 tons. The qualities of a vessel depending much on its form, it is not possible to deduce a very precise rule for proportion abstracted from shape; but the following list of dimensions is deduced from a comparison of the dimensions of the best vessels, and will serve as a standard of reference for the existing state of practice. The following are dimensions of flush-decked vessels without poops or forecastle. Where these exist, the depth must be diminished so as to leave the mean depth the same. Thus, in the table, a vessel of 180 feet long by thirty feet beam, has twenty feet depth; but with a half-poop she would require to be only about eighteen one-half feet deep.

Table of Dimensions of Sea-going Steam-Vessels of the best proportions, in conformity with the best practice in Britain.

Length between the perpendiculars.	Breadth between the paddles.	Depth, hold, and midships.	Tonnage. Old law.
90 feet,	16 feet,	7 feet,	110 tons,
96	16½	7½	118
102	17	8	140
108	18	9	168
114	19	10	197
120	20	11	230
126	21	12	266
132	22	13	306
138	23	14	350
144	24	15	397
150	25	16	450
156	26	17	505
162	27	18	565
168	28	19	630
174	29	20	700
180	30	21	776
186	31	22	856
192	32	23	941
200	33	24	1044
205	34	25	1136
210	35	26	1231
216	36	27	1240
222	37	28	1455
228	38	29	1576
235	39	30	1712
240	40	30	1838
250	40	30	1923
300	50	40	3590

Steam Navigation.
Proportions, form, and structure of steam-ships.

The form of the ship, of course, affects very materially its qualities, and the choice of proportions to produce those qualities. The dimensions in this table apply to vessels of fine proportions, having a fine entrance and run, and a side nearly upright. If however the area of the load-water line be very large, the vessel will be uneasy even with these extreme dimensions; and in such a case the beam in the table is rather excessive, while the height might probably be augmented without inconvenience. Again, if the midship section of the vessel be very square, or merely rectangular, these dimensions will suffice. If however the bilges be round, and the sides slope outwards, more breadth may be usefully employed, so as to leave the breadth at the load-water line nearly equal to, or rather greater than, the beam given in the table.

River steam-vessels are, in this country, and especially on the Thames, made of great length in proportion to beam. Some of the swiftest river boats have their length equal to seven, eight, nine, and even ten times their beam, with advantage. In America they often have twelve times more length than breadth.

The Form of Steam-Vessels.—To determine the best form of a steam-ship may appear to be a much simpler case of the great problem of naval construction, than the formation of a sailing vessel. The principal desideratum in a steam-ship being the power of going fast through the water in the single direction of the propelling power, this case of the problem appears to approach much more closely to the construction of a solid that shall receive the least resistance in passing through the water, than to the case of the sailing vessel, which has to work with a propelling power which is generally in some other direction than that in which the vessel is designed to make way. In this point of view, the problem of the steam-ship is really a simpler case of the general problem than that of the sailing vessel. If, however, the steam-ship is also to be a good sea boat, and to work on some occasions under canvass alone, as well as under steam alone at other times, the problem at once assumes an aspect more complex than that of either problem taken by itself.

There is, however, a single fact which is important, as it very much simplifies the subject. Vessels built expressly for the purpose of steaming, and adapted for that purpose in the best possible way, have been found, when under canvass, to equal the fastest ships in sailing qualities. Their great length and fine ends prevent them from falling to leeward; their fast formation adapts them for going through the water; their boilers and machinery form a well placed and well distributed ballast; their fine ends and flaring bows render them lively as sea boats; and the small amount of their midship section, and small resistance, give them great speed under comparatively little canvass. This practical fact, that a vessel formed exclusively for steaming, and adapted for that alone, in the best possible manner, is found to be a good and fast ship under canvass, greatly facilitates the enquiry concerning the best form of a steam-ship. To this we now add another confirmatory fact, that the fastest schooners, cutters, smugglers, yachts, and slavers, approach more nearly to the form of the best steamers than any other class of sailing vessels. The problem of the best form of a steam-ship becomes thus not only simpler, but doubly interesting, from the reflex influence it may be expected to produce on sailing ships.

It is difficult, without going into minute technical details, to explain the peculiarities in the shape of the best steam-ships. The present state of practice shows that systems perfectly opposite are adopted by different builders. It is at all times difficult to convert into ver-

bal statistics forms so delicate and complex as the surfaces of double curvature formed by the bottom of a ship; but the following considerations of a general nature may probably be intelligible.

In the formation of steam-ships, it has been stated that there are opposite schools. One adopts and advocates a sharp bottom, a great rise of floor, great beam, extensive bearings on the surface, round sides, round waterlines, adopting altogether the formation of a full, capacious, stable, sea-going ship, only employing such dimensions and proportions as are given in the table of dimensions already produced. Another school adopts a flat bottom, long floor, more angular bilge, upright sides, straight entrance, clean run, sharp ends, comparatively small moment of stability, formed with the idea of going directly through the water in all weathers with the least proportion of resistance, and the smallest change of position. A third school, of recent origin, adopts the hollow wave lines and new formation, of which the principles have been established by the writer of this article. The fastest steam-vessels of the present day are built on this principle.

The question of form may be taken up under several heads.

The Transverse Section, or Midships.—The simplest and one of the earliest sections of a steam-vessel is the rectangle, fig. 26. the bottom being flat, the sides vertical, and the bilges almost angular. This form is rendered necessary when the breadth of the vessel over the paddles is to be rendered as small as possible. But this form, although it gives the greatest capacity when the breadth and depth of water are limited, is at once weak at the bilges, liable to crankness, and uneasy at sea. To remedy these evils, the bilges have been rounded, and the floor sharpened, in order to give more easy lines on the bottom, and an easier bilge, as in fig. 27.

Fig. 26.

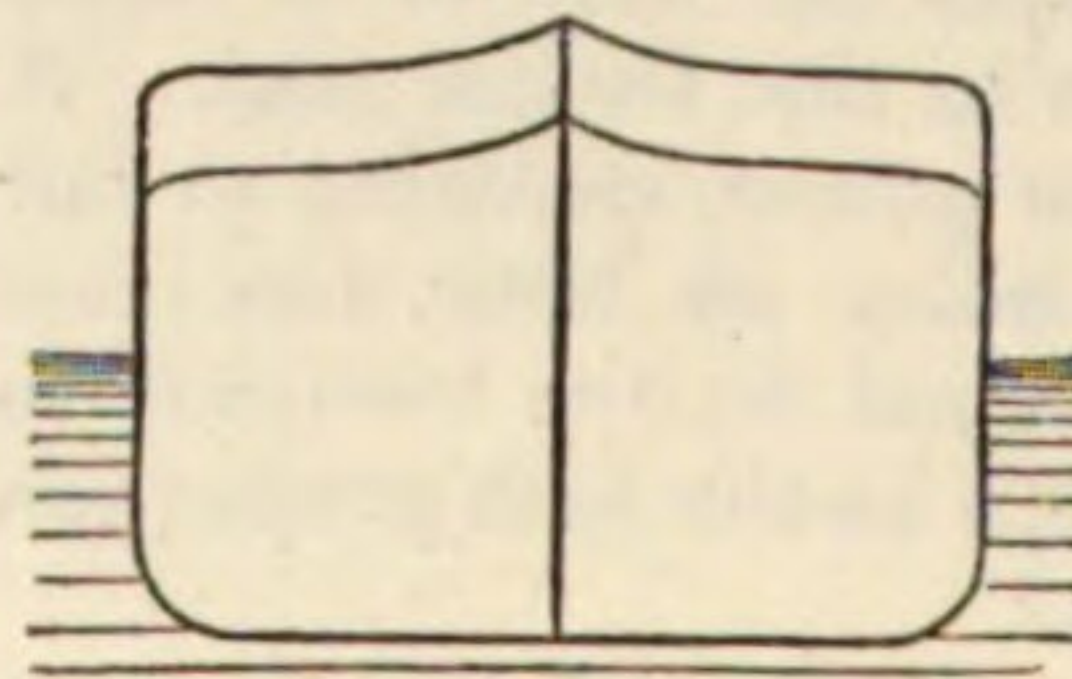
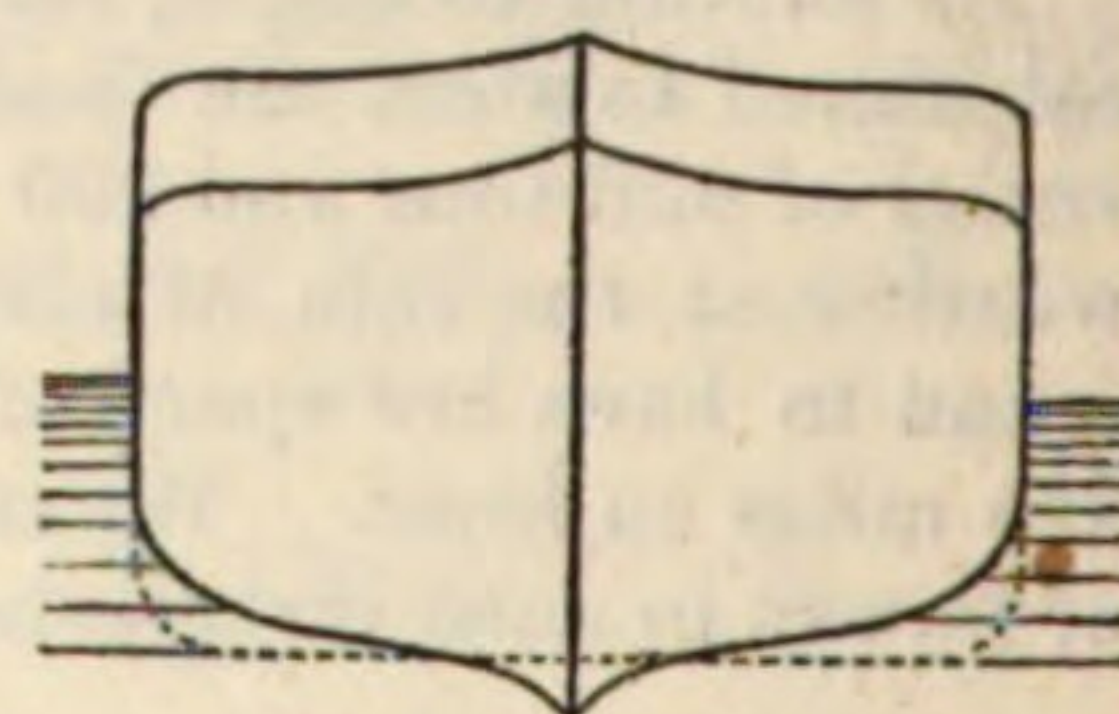
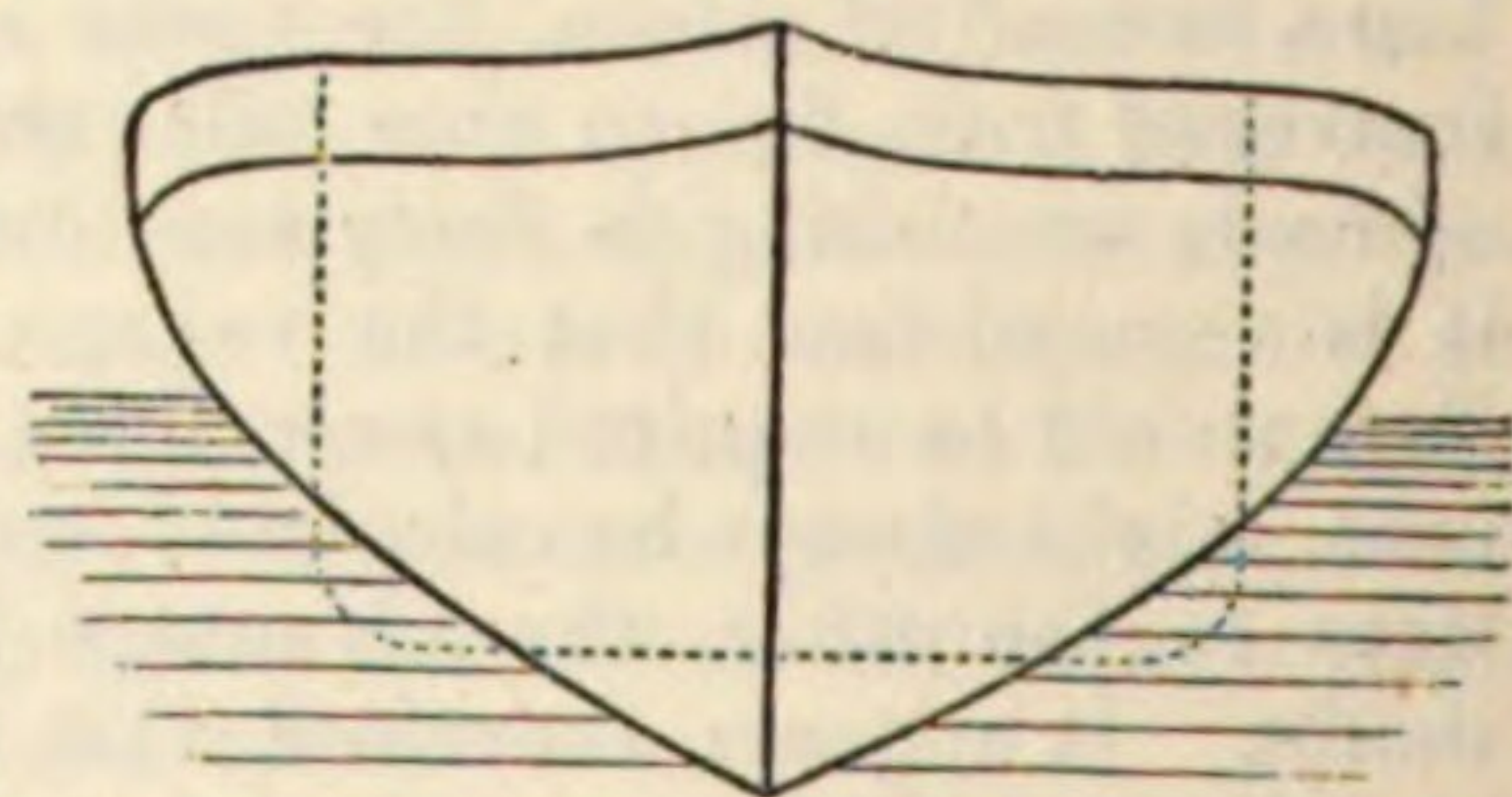


Fig. 27.



And again, this method has been carried to an extreme, or with the intention of producing the best possible sea boat, by making the floor very sharp, and the sides extremely round, thus:

Fig. 28.



But such boats are both unstable at sea, and pitch most violently. The next modes of construction have had for their object to produce the greatest capacity with the least material, and least surface of adhesion to the water. For this purpose semicircular and elliptical bottoms have been tried, thus:

Fig. 29.

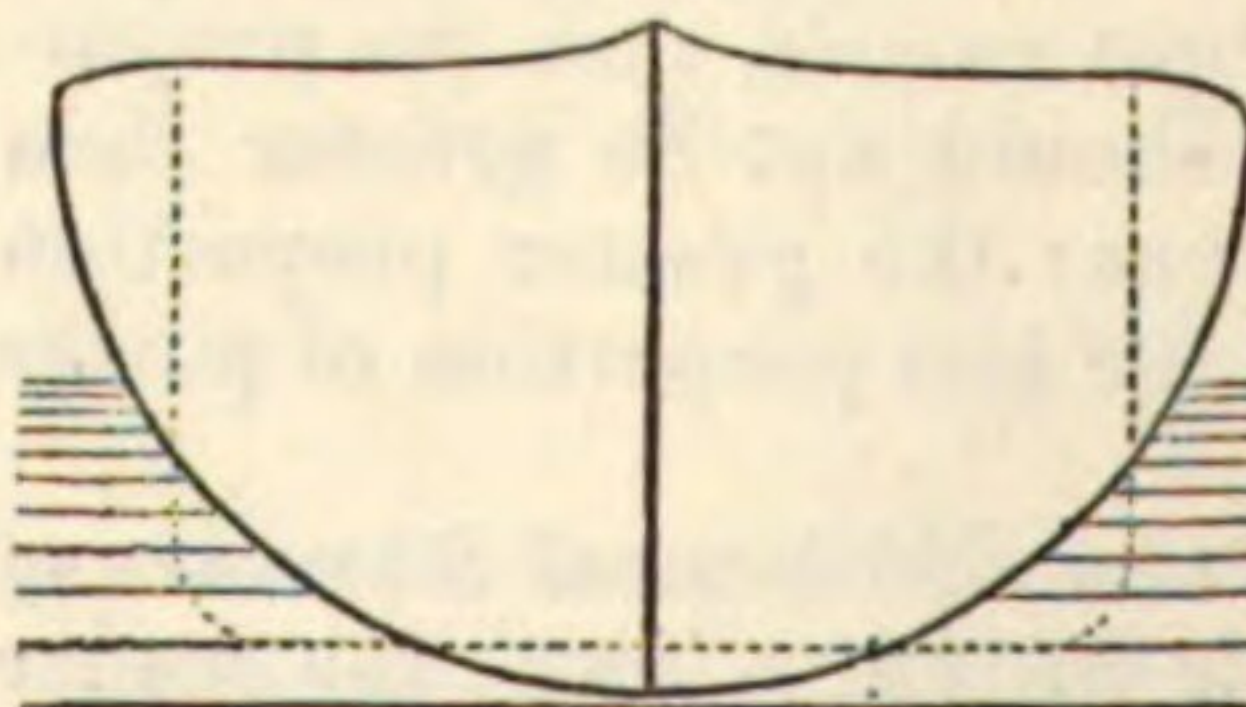
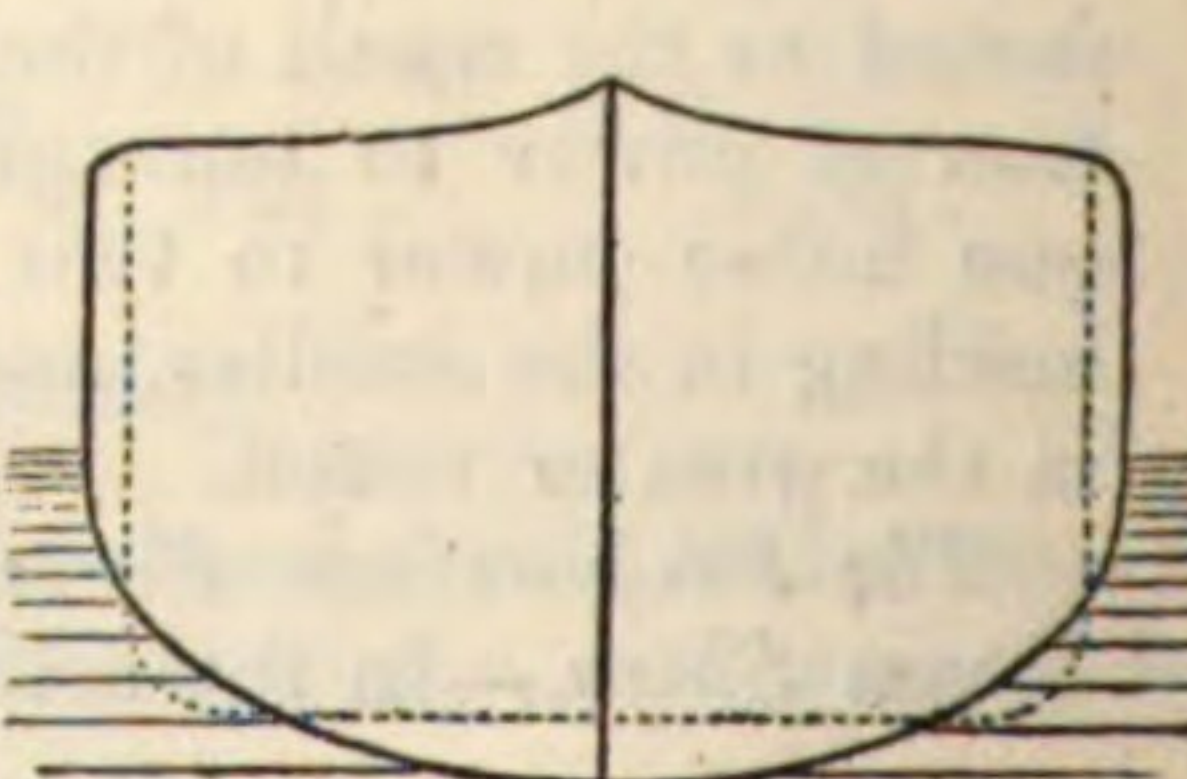


Fig. 30.



Steam Navigation.
Form of steam-ships.

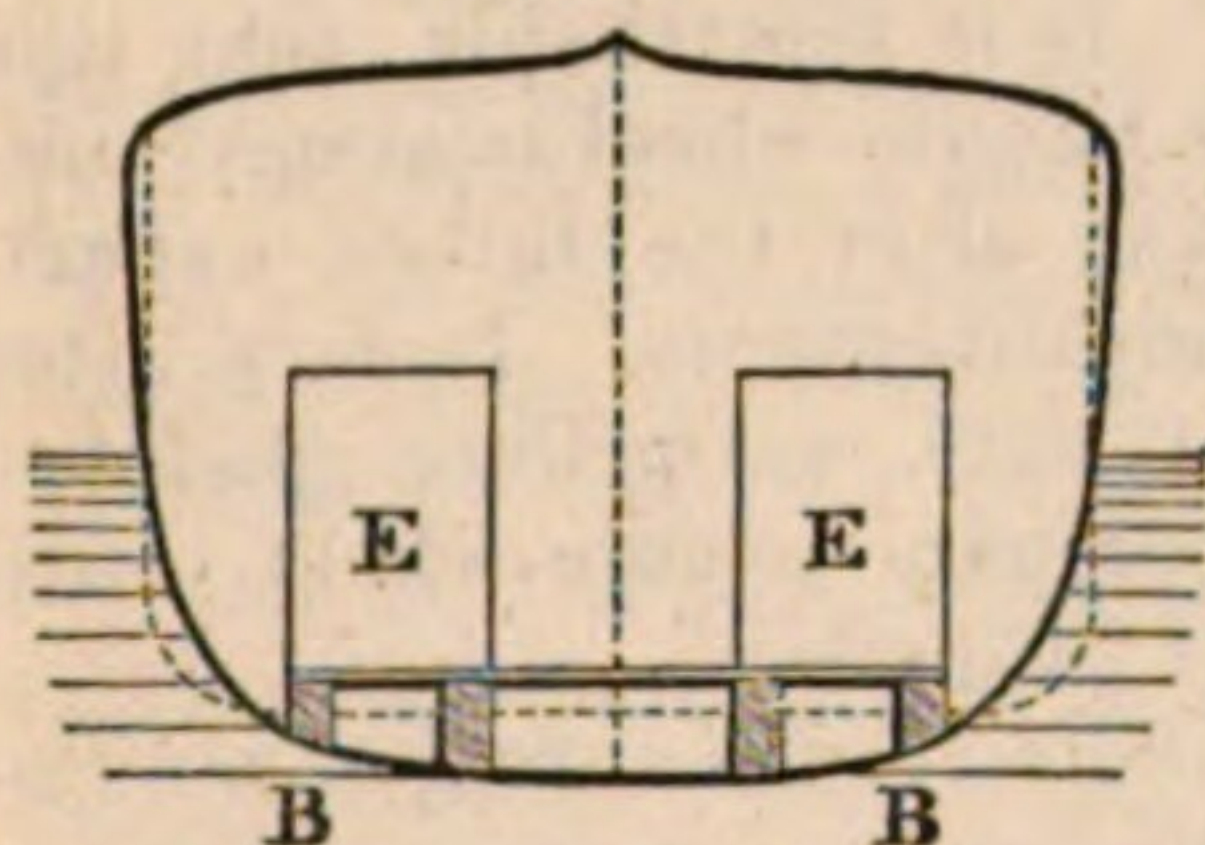
Steam Na- But both of these, and especially the former, although vigation. well suited for fast steamers, have a great tendency to oscillate continually, and roll with great latitude at sea.

Form of
steam-
vessels.
Midship
section.

It appears from experience, that there is great difficulty in determining that section of vessel best suited to a steam-vessel. The rectangular figure first given is, as we have said, at once weak, and crank, and uneasy. The sharpening of the bottom, as in the figures which follow it, removes the engines up from the floor, and effectively diminishes the height of the engine-room, as well as renders the vessel crank, by raising the centre of weight, and of the engines, &c., too high; and if, to counteract this evil, the beam at the surface of the water be increased as in the third section, the vessel is rendered laborious, uneasy, and ineffective at sea by the excessive beam. Again, in the round bilges the vessel swings like a pendulum, and it seems as if her oscillating would never stop. From the multitude of practical experiments which have come under our notice, we are led to the following conclusions.

1. That the existence of a fixed mass in the shape of engine and boilers, renders the usual mode of determining the midship section of a ship inapplicable to steam-ships; and that the form must be determined with immediate reference to these. 2. That the engines of a vessel of 300 horse power occupy a space of about $\frac{2}{3}$ of the beam of a ship, which necessarily is perfectly flat; and that the engine can only be firmly connected with this floor of the ship by being placed as directly in contact with it as possible; and further, that the weight of the said engine must be placed as low as possible, on account of the place of the paddle-wheel; all of which desiderata can only be obtained by making the floor of the vessel parallel to the bottom of the engine. Hence the bottom of the ship should be nearly flat across about $\frac{2}{3}$ of her beam, thus:—B to B, fig. 31, nearly flat, EE the engines. 3. That no displacement is desirable on each side of the engines beyond what is required to give

Fig. 31.



an easy turn to the bilge; for it is found, as indeed it should be expected, that all displacement on each side of the engines, at the lower part of the bilge, being vacant space, or very inefficient stowage-room, is not only wasted, but tends to impair the stability and sea-worthiness of

the vessel; and, further, the engines being placed low, a species of stability of the most valuable nature is obtained. 4. That there are two ways of obtaining stability; one by having the weight of engines and boilers as low as possible, which is obtained by the means already described, and by depth in the water; the other by considerable beam. Now, beam in excess is one of the worst features of a steam-vessel. It produces a rolling oscillation, when the wind is in any degree on the beam, which impairs exceedingly the action of the paddles; it gives a species of roll, which is at the same time most distressing to passengers, and most injurious to the ship. All these bad effects are diminished, and can alone be corrected, by obtaining stability as far as possible from depth of the centre of weight rather than beam, according to the midship section already given.

Water
lines.

The Water Lines.—Opinions on the subject of water lines, or on the degree and manner of fulness or fineness which the ends of a vessel should possess in reference to the middle, are as various as the deviations which one may conceive possible from any given shape. When with these we combine the differences of opinion concerning midship sections, which differences must also

affect very materially the form of water line, we get into a labyrinth of difficulties, in the intricacies of which the good qualities of a steam-ship are so often lost.

Steam Na-
vigation.

Full round ends, convex outwardly at the bow, full above at the stern, and fine enough below to steer well, so rendering the form as like as possible to an American cotton ship, with a long straight narrow body in the middle; such a form has been introduced for steam-vessels, in the hope that the vessels, by having a small midship section and great buoyancy, might be easily propelled through the water. Even when they are made seven times as long as broad, we have seen vessels of this class turn out failures. They have, in the first place, been crank, in the second place wet, in the third place slow, and in the fourth place weak; for, by having too much bearing at the ends, and too little where the chief weight is to be supported, viz. in the middle, they have invariably bent down in the middle, and risen up at the ends.

Form of
steam-
ships.
Water
lines.

Full round ends, combined with a full round midship section, are a modification from which much has been expected, as forming a ship of large capacity. This has been one of the worst and most extensive errors perpetrated in the construction of large steam-ships. The great breadth along the whole water line, arising from the full lines, gives an excess of superficial stability, which, with a cross sea, causes the vessel to roll violently, with an extent and abruptness of motion which the round form of the section has no tendency to prevent or retard. Then the full ends of the vessel prevent her speed through the water, and increase her motion in a heavy sea, by increasing to excess her longitudinal stability. In the next place, if the ends of the ship be used for stowage, it is plain that the great mass of matter at the two ends must render the ship labour-some, or the reverse of lively, according to the nautical phrase; and the ship will less readily obey the helm. Such are some of the evils which, in many instances, and those especially in steam-ships of the largest class, have been seen to result, and which necessarily must result, from the full and round-bodied vessel used in steam navigation.

These are not all the evils of the full form. The stowage of such vessels is by no means effective in proportion to the weight, capacity, and displacement of the ship. In the first place, by giving much space on both sides of the engine-room, a very inferior species of stowage is obtained to that which results from additional length of hold. Next, the stowage-room in the end of the ship, for which so much speed is sacrificed, cannot be made effective without rendering the ship unseaworthy and unmanageable; for it is notorious, that in order to rectify the erroneous fulness for which so much is sacrificed, the ends of the ship are bulkheaded off to obtain the valuable quality of liveliness. First, then, fulness is obtained at a sacrifice of speed and seaworthiness for some supposed advantage in capacity, &c.; then, that very capacity is rendered ineffectual by the injudicious mode of its application.

An opposite school from this recommends the long straight centre body of a ship, with rectangular sections and sharp, fine, wedgelike ends. This form possesses the advantage of small transverse sections, and gives great stowage: it is an easy sea boat, and is lively from its fine ends. The principal fault in this form of vessel is its liability to crankness—its weakness at the bilge. Many of the finest steam-ships belong to this class.

The last class to which it is necessary to make a particular reference, are the steam-ships recently constructed on the wave-lines, or the hollow entrance line—on the principle which the writer of this article, by experiment and by example, has laboured to introduce. The

Steam Na-
vigation.

Form of
steam-
ships.
Water
lines.

first vessel of this form was an experimental one of 75 feet keel, laid down in 1834. The next was a steam-vessel of 100 feet keel, constructed in 1835. The next were two pleasure yachts of Mr Ashton Smith, a wealthy proprietor in Wales, whose observation on vessels had independently led him to the conclusion that hollow lines and a peculiar midship section gave the easiest and best sea steamers; and both of these vessels, of 1838-39, though merely approximations to the true wave-lines, were remarkable for their speed and other excellent qualities. The fourth vessel of this class was the Shandon steam-vessel, altered from the old to the new lines, 1840, with a gain from the same engine of from two to three miles an hour in speed. This vessel is the property of Mr Robert Napier. The next and last vessel is the Flambeau, built in 1840, on the wave principle, by Mr Duncan of Greenock, with the co-operation of the present writer. This vessel, with the smallest proportion of power to tonnage, and with the smallest supply of steam, is, nevertheless, by far the swiftest vessel on the Clyde. The Fire-king, the largest of this new class of vessels, is 660 tons, and has engines of 220 horse power. The Flambeau has only 70 horse power to 280 tons measurement. Vessels of this class have been found at sea to be both easy, stiff, dry, and lively; while they are by far the fastest vessels of their power. The speed of the Fire-king, now the property of Mr Robert Napier, is fifteen miles an hour in still water. The speed of the smaller vessel, the Flambeau, with very deficient steam, is fourteen miles an hour; a velocity which, with her small proportion of steam-power, is only to be attributed to her superior form, and the slight degree of resistance which she encounters from the water.

The principle on which these wave-ships are constructed is, that the hollow lines forming the entrance are to correspond, as nearly as may be consistent with the form of a ship, to the form of a certain wave capable of moving with the same velocity as the vessel. The analogy between the displacement of the water by a wave of the first order, and its displacement by a vessel moving with the same velocity, being so very close as to approach to identity, rendered it probable that the same mode of displacement would be followed in both cases with the same result, viz. the production of minimum resistance. It was further to be anticipated, that as a wave, when allowed to follow the usual mode of displacing the particles of water over which it passes, presents a smooth and unbroken swelling surface, so the vessel, if of the proper shape, according to these wave-lines, would divide the water at the bow in a smooth, unbroken sheet, instead of showing the usual head of water or surge exhibited at the bow of ordinary vessels at high velocities. On the other hand, when a wave encounters a shapeless rock, or breaks on a rugged coast, it exhibits the same violent surges which are presented on the bow of vessels of the usual form. Thus, then, the analogy leads us to suppose, that the smooth, continuous, resisting displacement of a wave, would be the best method of displacement for a vessel. On submitting the question of least resistance to the elementary calculation, it appeared that the form of least resistance was very close indeed to that of the wave. The science of hydrodynamics is not, however, sufficiently matured to enable us to place implicit dependence on all the results of its calculations, unless where they are supported by actual observation; and it therefore became necessary to make the experiment.

For the purpose of determining whether this form were that of least resistance, an experimental vessel, about seventy-five feet long, was constructed on a hypothetical form of least resistance, with the wave water lines.

When this vessel was propelled at the rate of seven-teen miles an hour through the water, it was found, that instead of the usual surge exhibited at the bow of other vessels, the water was parted so smoothly and quietly, that no white spray nor other symptoms of high speed and great resistance were visible, and the parted water returned peaceably to the place it had occupied previous to the transit of the boat, with only a slight translation forwards. It appeared, therefore, from the experiment, that no greater quantity of motion was communicated to the water than was necessary to permit the vessel to pass through, and with no greater velocity than the speed of the vessel demanded. It was then presumed that this form was that of least resistance; and all subsequent experiment appears to demonstrate the truth of this inference from fact, as predicted by analogy and calculation.

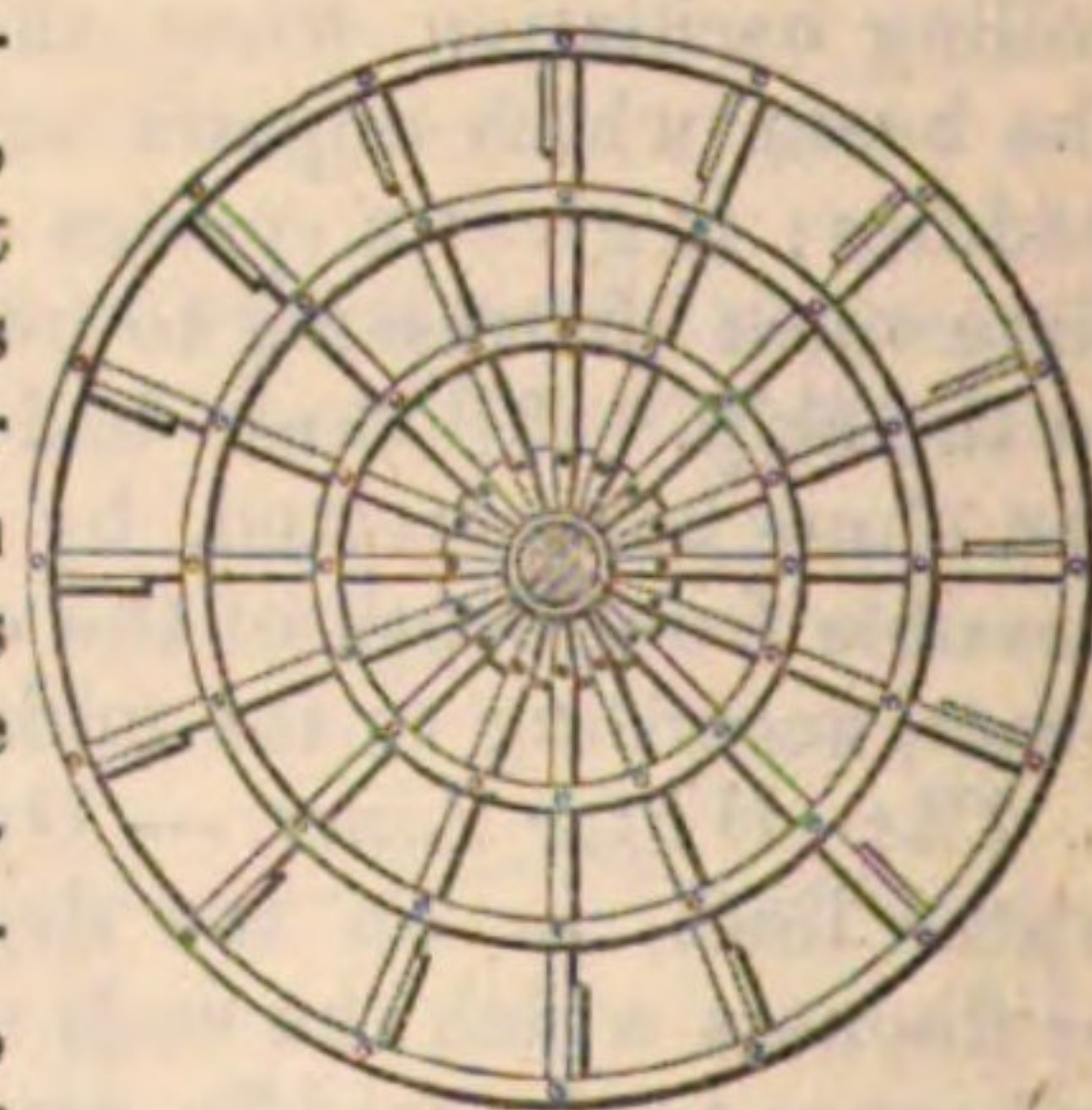
It is also worthy of remark, that this form is capable of being combined with all the good qualities of a steam-ship, such as strength, dryness, easiness, as well as great speed; but as the construction of such vessels may still be deemed an experiment in progress, the writer will not occupy more space with observations on his own researches. Thus much he felt it his duty to communicate, in order to adapt this article to the most recent condition of steam-navigation.

The immediate Mechanism of Propulsion.—The Propelling paddle-wheel of the ordinary form (as given in the Mechanism plates) seems to be the most perfect, as it is the most simple means of propelling vessels through the water. The idea soon occurred, that as the steam-engine is calculated to turn round wheels, it is only necessary to place, on a wheel on the outside of a boat, large teeth or paddle-boards to take hold of the water, and so drive the vessel forward by simply turning the wheel. It was this plan that was adopted by Jonathan Hulls, in the first plan of a steam-vessel. But there is no piece of mechanism (if we except, perhaps, the crank of the steam-engine,) which has been more despised, or which more strenuous and frequent attempts have been made to improve or supersede, than the common paddle-wheel. It is remarkable, that like the crank steam-engine, the paddle-wheel is almost universally employed in practice, after the fullest experiment of many diversified improvements. In fact, after experiments of all sorts of oars, propellers, paddles, chaplets, screws, &c., the common paddle-wheel continues to predominate as "the propeller."

The numerous faults attributed to the common paddle-wheel, are chiefly faults of misconception or malconstruction. It is easy to account for both.

When a steam-vessel is at rest in a harbour, and prevented from moving, or when in the act of setting out into motion after having been at rest, the defects of the common paddle-wheel appear to be very great. The paddle-boards, fig. 32. on entering the water, press obliquely down into it, tending to raise or lift the vessel up out of the water with a force which produces no useful effect. Again, when the paddle is rising out of the water behind, it seems to do little more than raise or drive the water upwards in the form of back water. It is only, therefore, in the middle of its path that the propulsion of the paddle seems exerted in forwarding the boat, and that only for a very short time. A large part of the force of the steam-engine seems thus to be expended in raising up the vessel, and

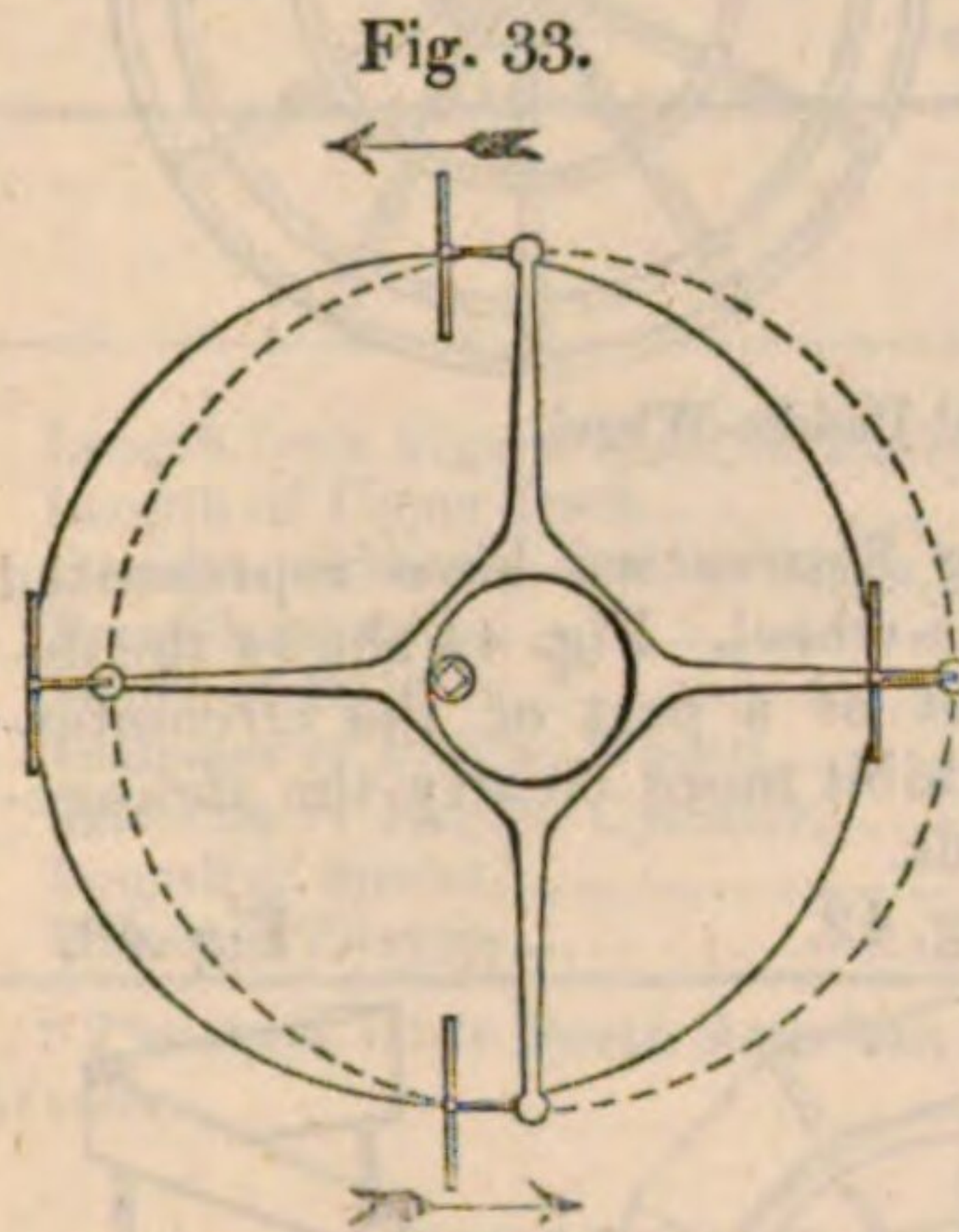
Fig. 32.



Common
Paddle-
Wheel.

Steam Navigation. Propelling Mechanism. in elevating back water, and only a small portion in carrying forward the ship. But this is the case of a vessel at rest or not in rapid motion. Now it is argued from this view of the case, that the only way in which a paddle-wheel could be made efficiently to perform its propelling duty, would be, by giving the paddle-boards such a motion upon themselves as to keep them always in a vertical position, both on entering the water and on emerging from it. This was effected about the commencement of steam navigation by Mr Buchanan of Glasgow, in what may be designated the parallel paddle-wheel.

Parallel Paddle Wheel. Buchanan's.



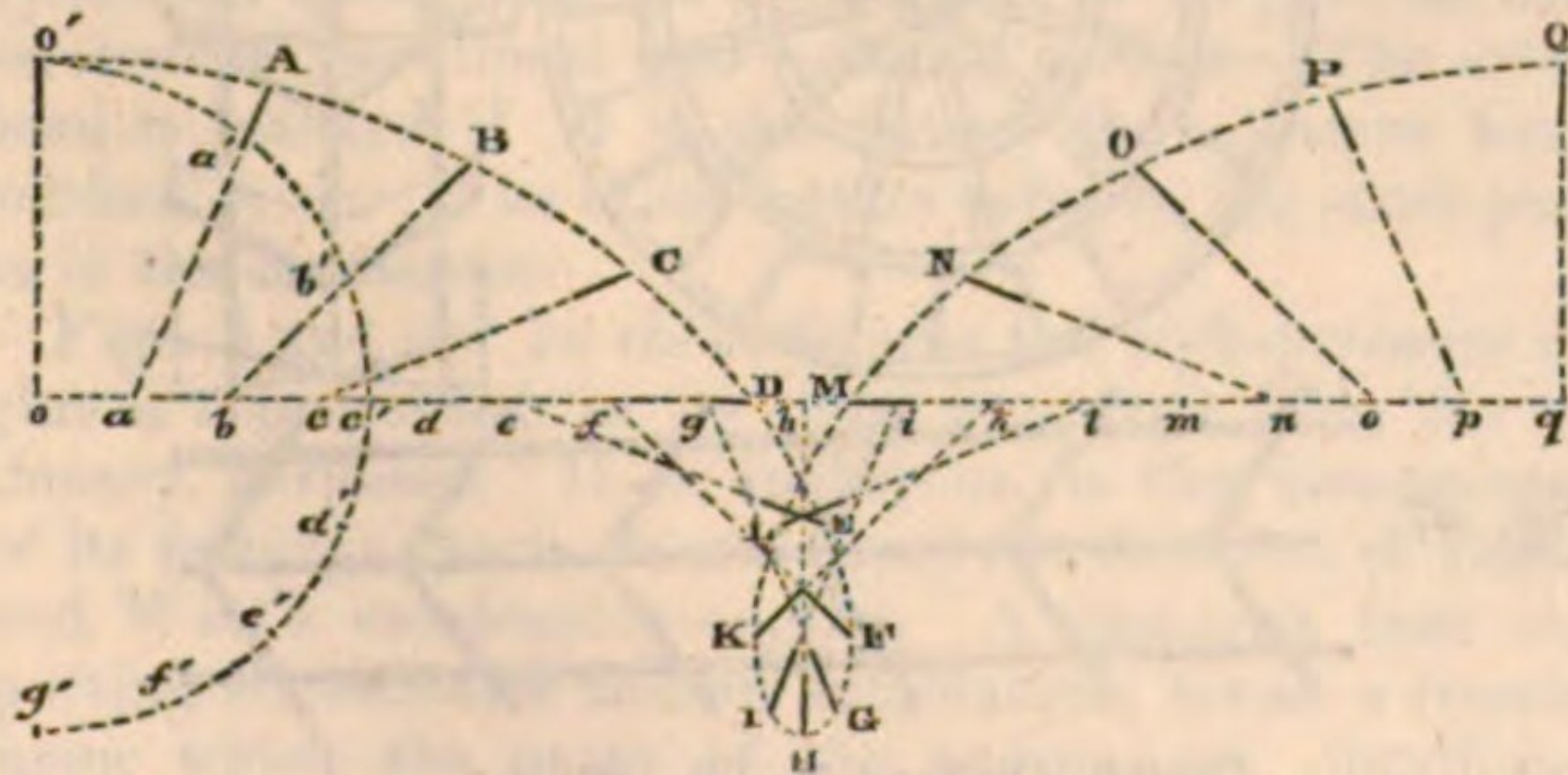
The parallel wheel, fig. 33 is constructed on this principle, "that if two equal circles be equally divided, and so placed, that the distance between two of the points of division is equal to the distance between the centres of the circles, then will all the other points of division be also equidistant, and all the straight lines joining them be parallel." By giving to each paddle-board re-

volution on an axis, and placing an arm at right angles to it, connected by a junction-bar with an eccentric strap around the axis, the geometrical problem is mechanically constructed, and we have Buchanan's parallel paddle-wheel. This wheel, with and without alterations in mechanical structure, has been invented and reproduced over and over again. It has always failed, being radically bad.

Analysis of the action of the common Paddle Wheel. In truth, the phenomena of a paddle-wheel revolving on a steam-boat, when the vessel is in motion, differ essentially in their form and effects from the phenomena of a wheel revolving around a centre which stands still.

When the vessel is only starting, or as yet moving very slowly, all the evils here mentioned do in some degree take place; but by the motion of the vessel forwards, which is the result of the revolution of the paddles, the evils complained of are at once remedied, and the paddle of a common wheel in a quick vessel is actually "feathered," according to the most dexterous toss of the practised rower. A little study of the geometrical conditions of a paddle moving forwards and in a circle at the same time, will make this plain. Let us trace for this purpose the motion of a single paddle. At the point o , the paddle-board O' being in the position O' , the

Fig. 34.



wheel, turning on a stationary axle, would bring the board o successively into the positions $a', b', c', d', e', f', g'$ &c.; but the axle being advanced by the motion of the boat into the places $a, b, c, d, e, f, g, h, i, k, l, m, n$,

VOL. XX.

o, p, q , in the same intervals of time, and these motions being simultaneous, the paddle-board describes a path in reference to the water which is the result of both, and the successive positions of the paddle-board are $aA, bB, cC, dD, eE, fF, gG$, &c. The paths described by the boards are trachoidal curves, being of the family of the cycloid. Now, from the study of the actual motion thus performed by the paddle-board of the common wheel, it is plain, first of all, that the paddle is inserted into the water in an angular position resembling closely the entrance of an oar into the water; that it is then made to act horizontally on the water during a short interval; after which it is withdrawn from the water, edgewise, in an easy and elegant manner, which the dexterous rower might envy and try to equal, but which he could hardly excel.

All this, however, takes for granted that the paddle and the boat are well proportioned and placed; otherwise all this perfection may be impaired or lost. To this exposition of the subject, it may be added, that the common paddle-wheel is in practice, as it ought to be in theory, exempt from the faults generally attributed to it; and that experiment has shown that its action presents as much perfection in operation, as its simple form and mechanical arrangements do in enabling the artist to give it durability and strength.

When the paddle-wheel is badly proportioned, badly placed, attached to a very slow or full boat, or immersed too deep in the water, its action becomes impaired or impeded. Hence much attention has been devoted to the construction of a paddle that should be more effective in these unfavourable circumstances than the common wheel; in short, to construct a paddle-wheel that should be an effective propeller, even when immersed to its axis, or wholly placed under water. This may be properly enough called the radiating paddle, as distinguished from the parallel paddle.

The radiating paddle is not constructed on the fallacious view of the subject which gave rise to the invention of the parallel paddle-wheel. On the contrary, it proceeds on the hypothesis, that the actual motion of a paddle-wheel on a moving ship is cycloidal; and its intention is to adapt the wheel with greater perfection to that cycloidal motion. The theorem on which it is founded is as follows. Let the circle in the following diagrams, figs. 35, 36, represent that circle in a paddle-wheel which is described by a point moving in the common cycloid, that is, where velocity in the circle is equal to the velocity of the vessel, o being the centre of the paddle-wheel,

Fig. 35.

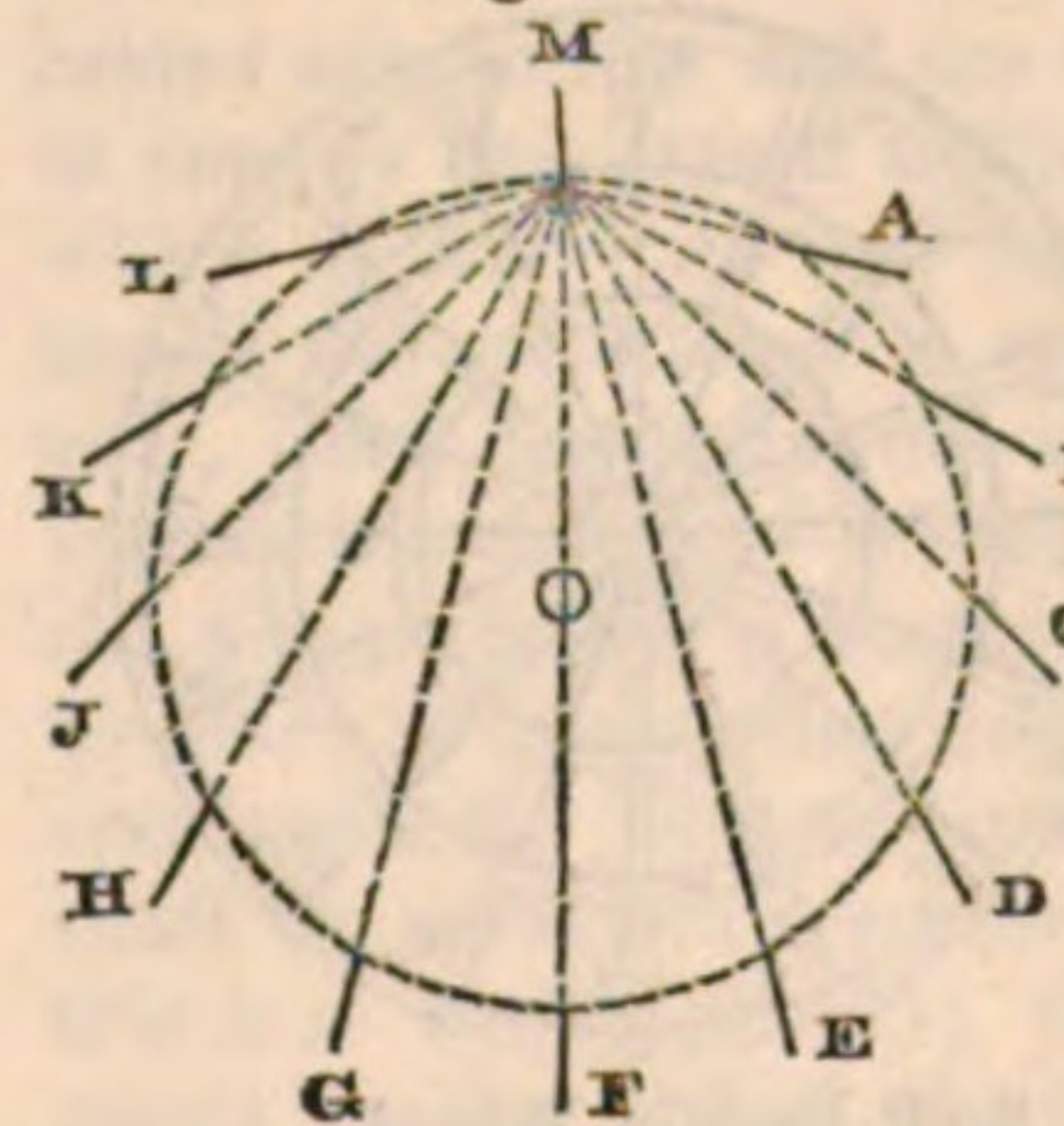
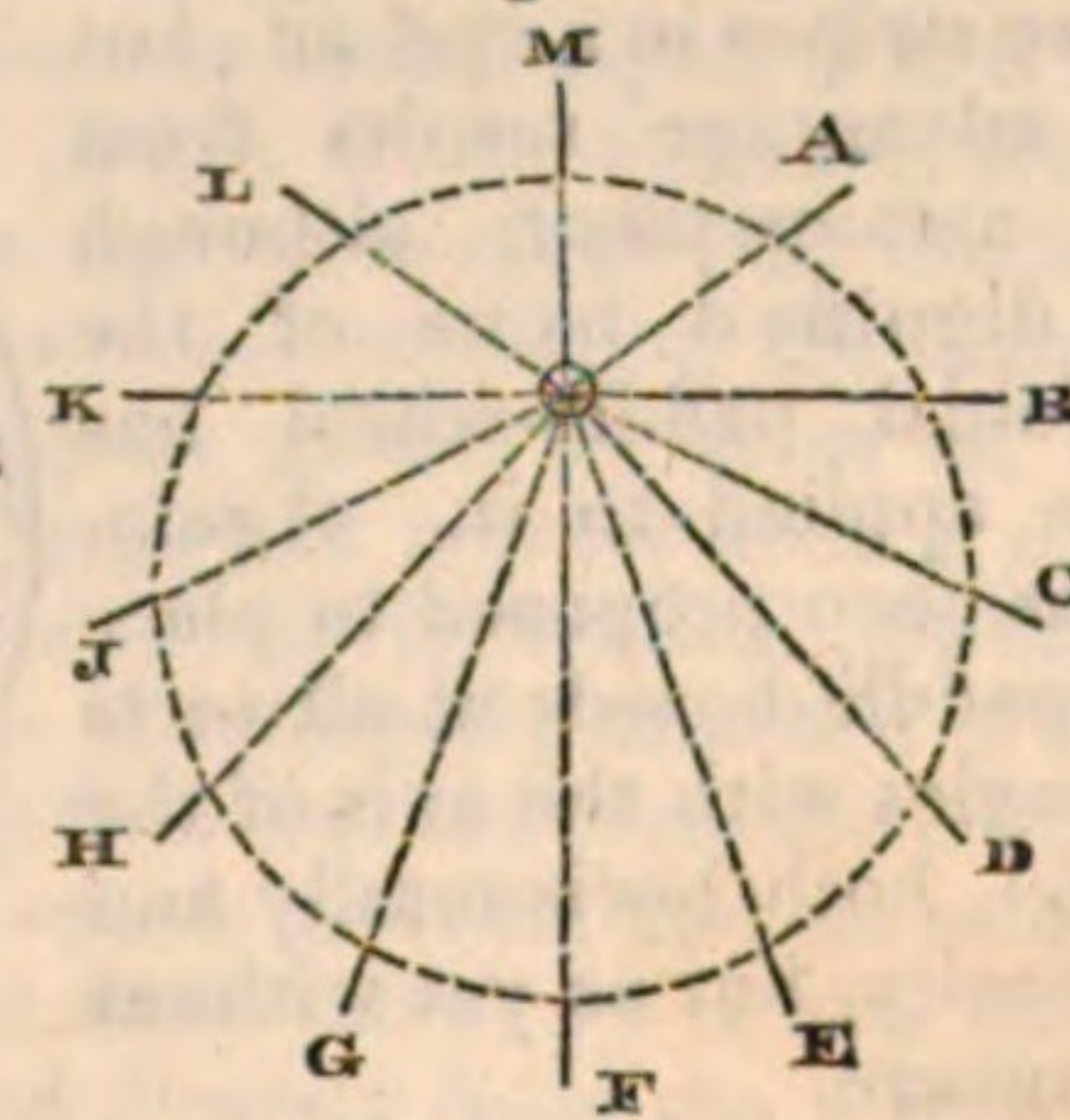


Fig. 36.



then, by the property of the cycloid, all lines drawn from the point M at the superior extremity of the vertical diameter of that circle to A, B, C, D, E, F, &c., points in its circumference, will be parallel to the cycloid of progression, or rather to its tangents, at the points of its periphery which correspond to A, B, C, D, E, &c., when in motion. If it were possible to construct this

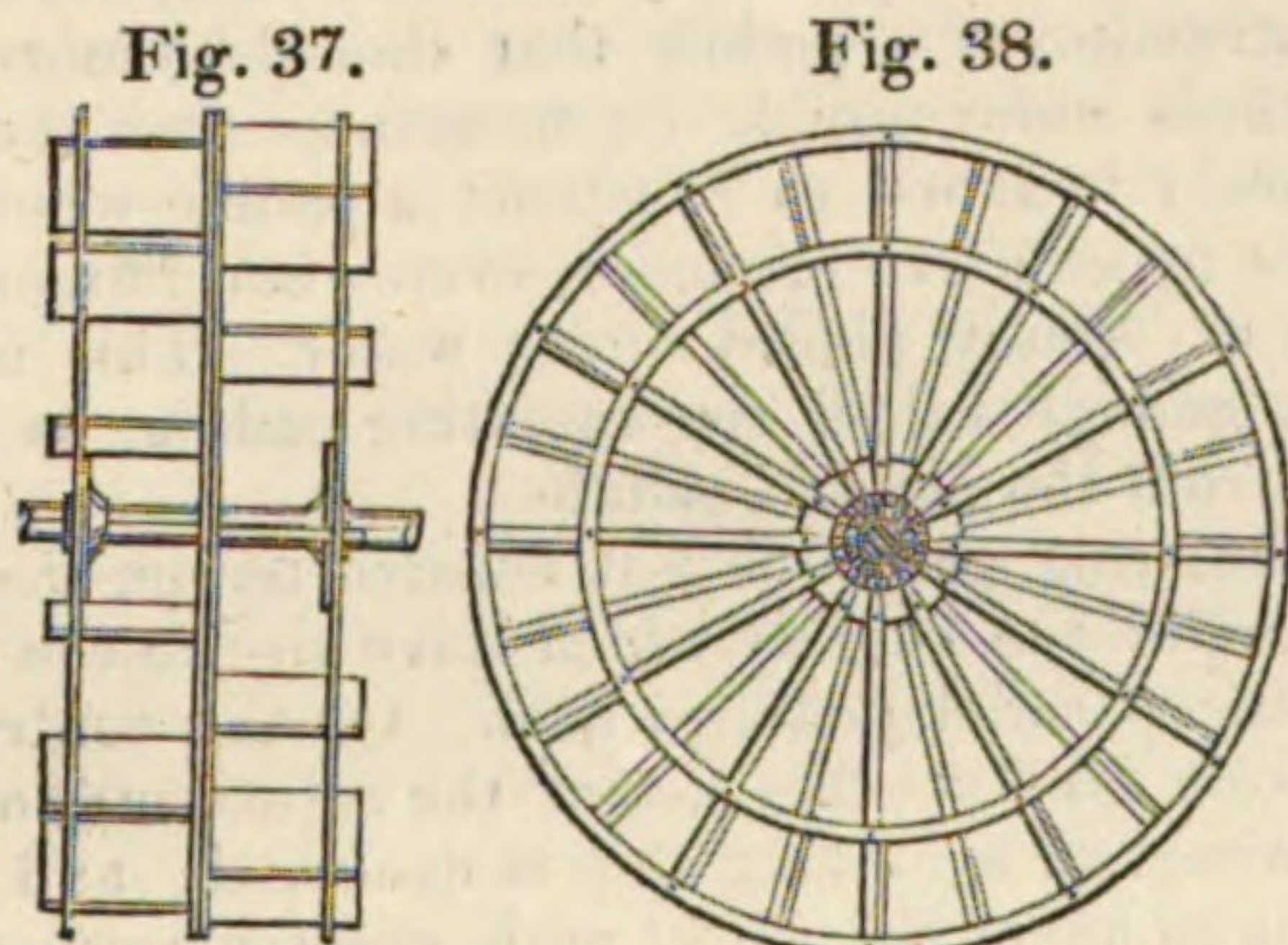
4 U

Steam Na-
vigation.
Propelling
Mechan-
ism.

geometrical problem in a mechanical apparatus, this paddle-wheel would have great efficacy even when very deeply immersed. It is, however, difficult to make this motion perfect at M. But this species of mechanism has been very beautifully combined and arranged by Morgan, Seaward, Cave, and others, whose geometrical apparatus is very beautiful. Unhappily the apparatus, even in its most perfect state, is only correct for a single velocity of vessel and of wheel: for a different velocity, the point of radiation of the paddles must be changed, or loss is at once incurred. Hence it is found that this apparatus, like the common paddle, is liable to imperfections of action, with every change of immersion and velocity. When to this there are added the complexity, friction, cost, wear and tear, liability to accident, of this moving mechanism, introduced for obtaining the partial remedy or slight amelioration of an evil which by proper arrangement is but slightly felt under the old method, it becomes manifest, that the general abandonment of the radiating paddle-wheel, and the return to the common one, has not been without sound practical reason.

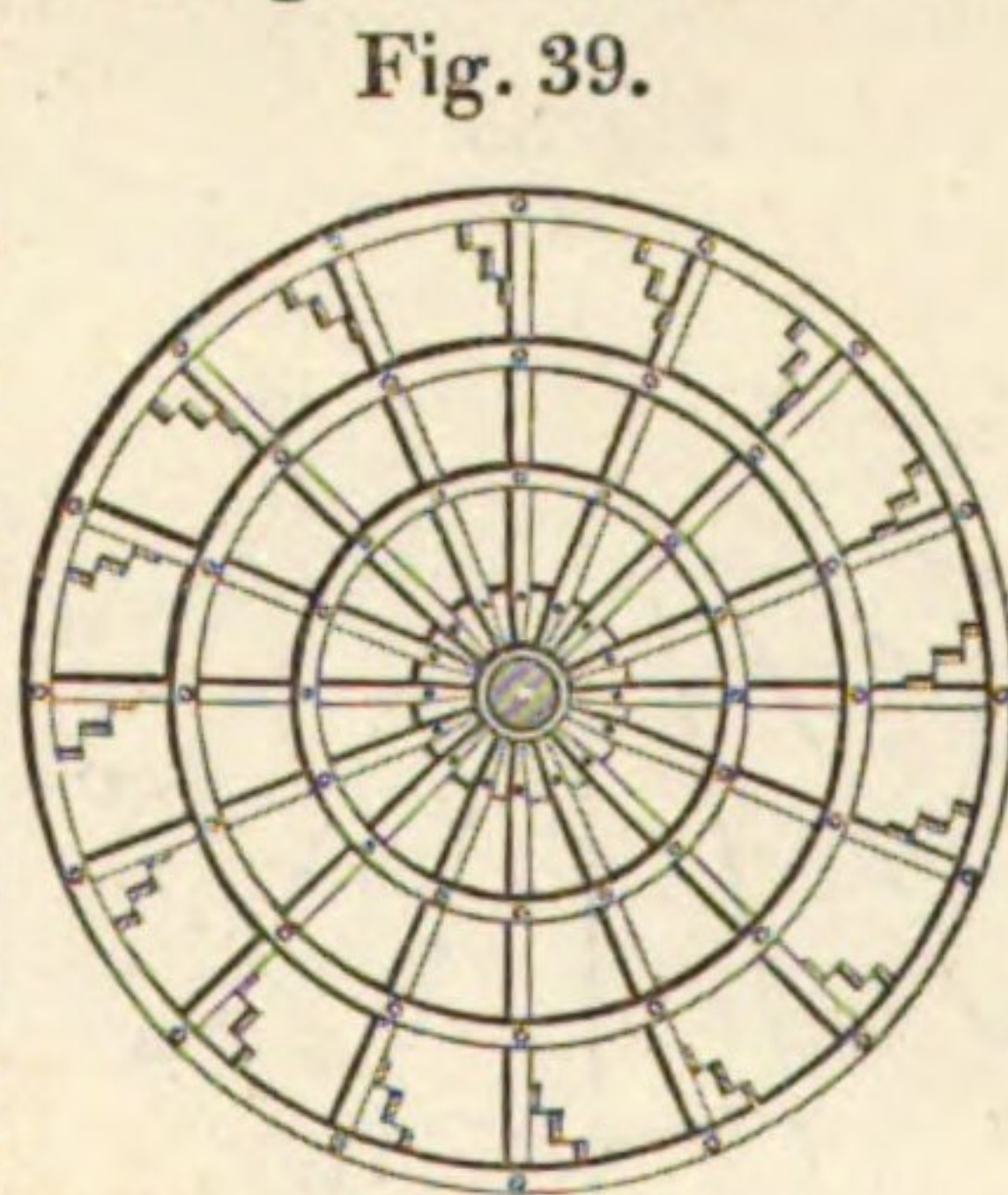
Divided
Paddle.

The last species of paddle-wheel is that with the fixed float: in other words, the simple paddle-wheel with boards placed around its rim. Of this there are various modifications. A very simple modification is that mentioned by Mr David Stevenson, in his excellent work on the civil engineering of America. The paddle-board of the usual wheel is, as it were, cut in two, one-half being placed half an interval in advance of the other, as in figs.



Split
Paddle.

37 and 38. This may be called the divided paddle-wheel. The concussion of a paddle-wheel striking the water is much lessened by this means, and the propelling force is rendered more nearly uniform. Another form of this wheel may be named the split paddle-wheel, from having the paddle-board, as it were, split into two or more horizontal slips, by which the same advantage is obtained as from the divided paddle-wheel. It has been proposed to place these stripes in a cycloid; but no advantage results from the arrangement, although the dignified name of the cycloidal paddle-wheel has been applied to it. Again, it has been proposed to place the paddle-boards at all sorts of angles with the axis of the wheel, both horizontally and vertically, but as yet without advantage.

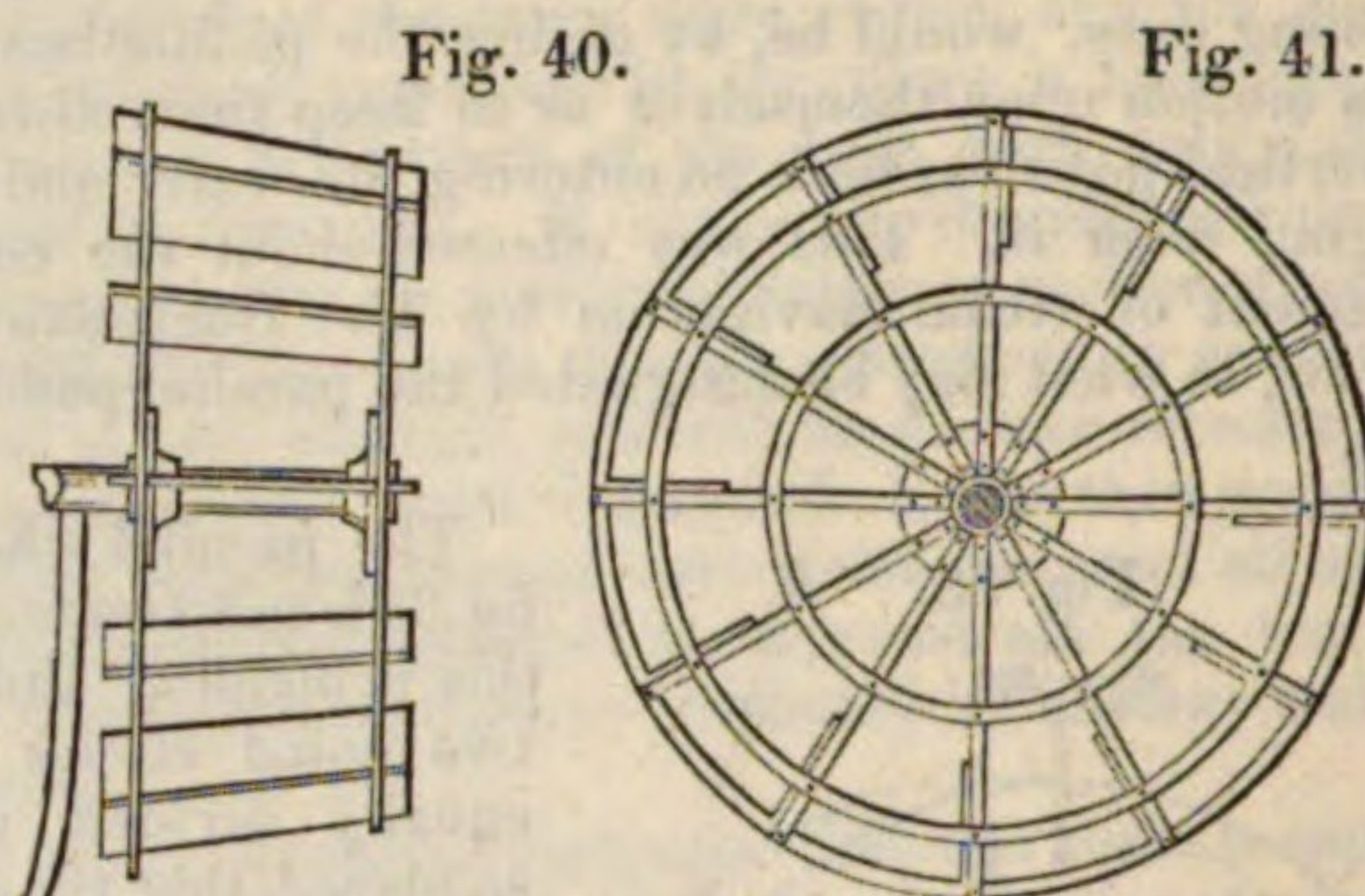


Split Paddle-Wheel.

A very simple expedient tends to remove all considerable irregularity or concussion from the common paddle-wheel. It is to allow the extremity of the paddle-board nearest the side of the boat, to descend from six to twelve inches deeper in the water than the outer extremity. This plan was carried into effect by the writer on a steam-vessel in 1836. The desired object was at-

tained without any sacrifice of power or speed. For distinction we may call this the conical paddle-wheel. It is shown in figs. 40, 41.

Steam Na-
vigation.
Propelling
Mechan-
ism.



Conical Paddle-Wheel.

In the three following figures we have represented the single oblique paddle-wheel. Fig. 44 shows the development or stretch-out of a part of the circumference of the wheel, to exhibit more clearly the arrangement of the paddle-boards.

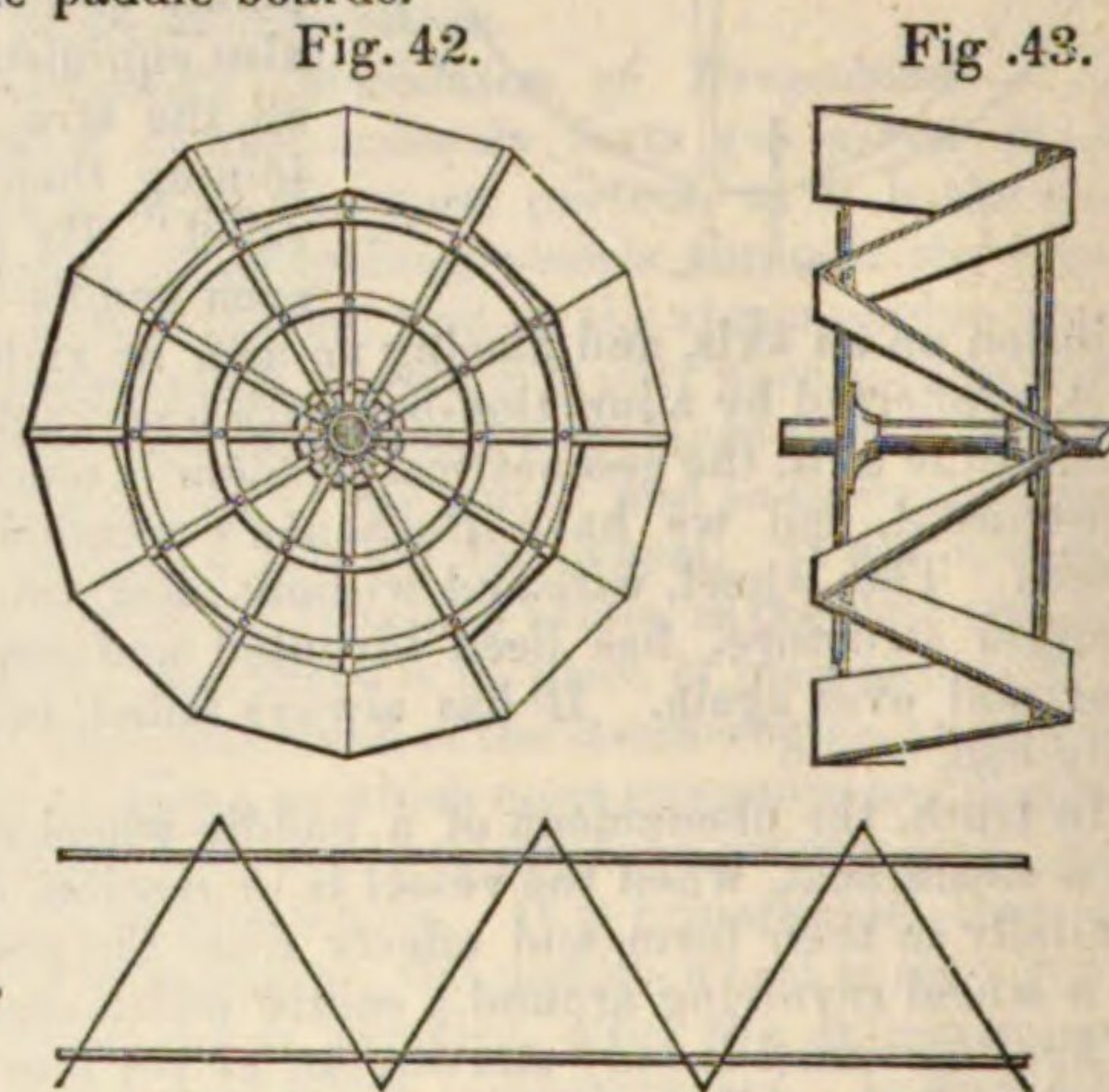


Fig. 44.

Single Oblique Paddle-Wheel.

In figs. 45, 46, the double oblique paddle-wheel is represented; and in figure 47 the development of a portion of its circumference is given.

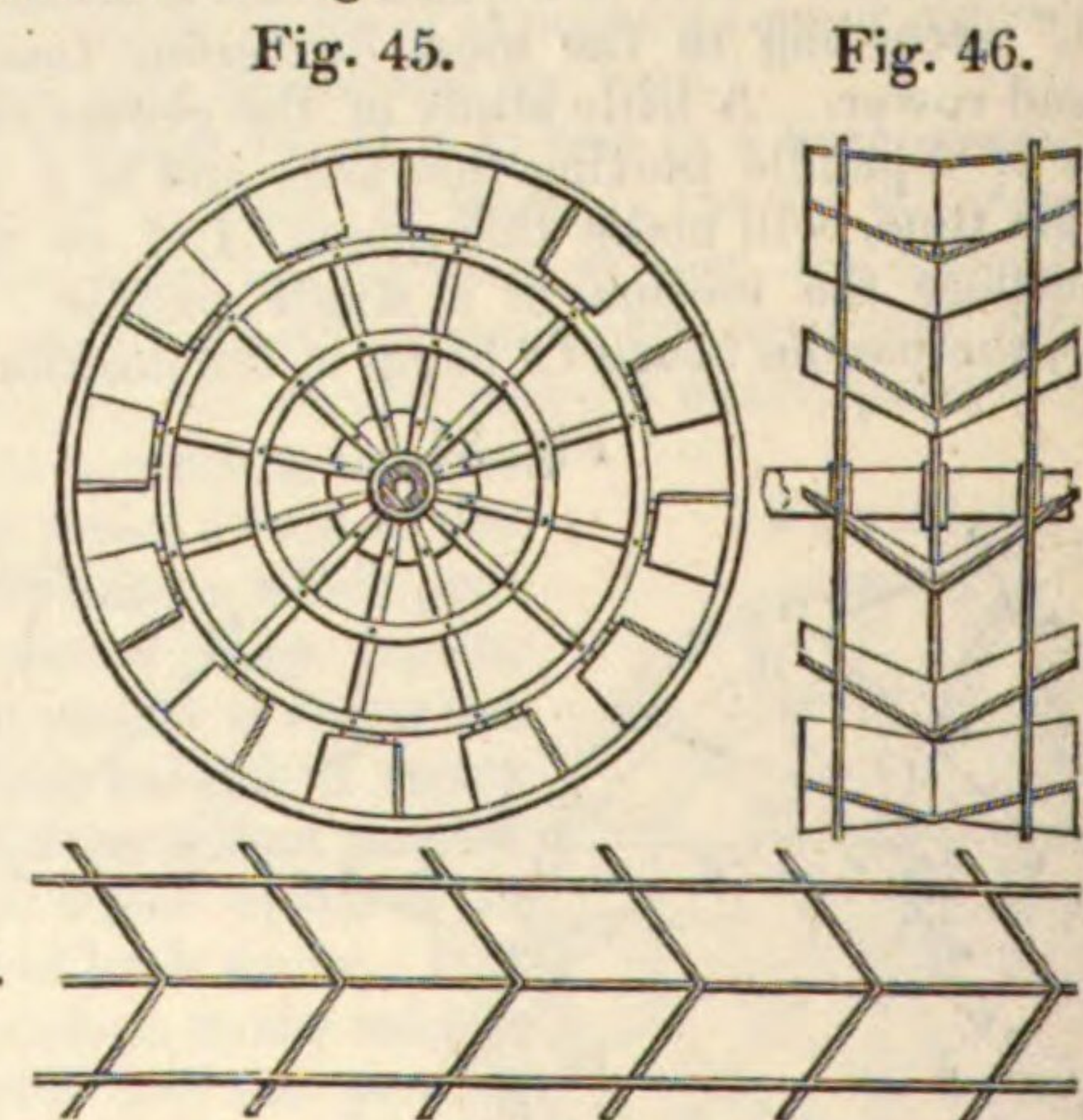


Fig. 47.

Double Oblique Paddle-Wheel.

The Reefing Paddle.—One of the greatest improvements on paddle-wheels, and one of especial importance to steam navigation, still remains to be invented

Steam Na-
vigation

We mean such a mechanism as shall enable the steam commander to set out on a long voyage deeply laden, with a small diameter of paddle-wheel; that is, with the paddle-boards near to the axis, and to increase the (effective) diameter of the paddle, that is, to remove the paddle-boards farther from the axis, as the vessel proceeds on her voyage and is lightened by the consumption of coal. The invention of a durable, economical, and safe apparatus still remains to be made. In the infancy of steam-navigation, Mr Buchanan of Glasgow published an account and drawing of a reefing paddle;

Messrs Bolton and Watt are also in possession of a very old method of reefing paddles; the Society of Arts in Scotland offered a prize several years ago for the invention, without obtaining, out of many plans, one to be recommended for practice; and, finally, the indefatigable inventor, Mr Hall of Basford, has patented a very elegant mechanism for the same purpose. It still, however, remains to introduce and establish a perfect reefing apparatus, and the author of such a system will render the common paddle-wheel a perfect propeller.

Steam Na-
vigation.

The following Table exhibits a comparative view of the Size and Power of six of the largest of the recently constructed Vessels for Transatlantic navigation.

	NAME OF VESSELS.											
	British Queen		President		New York.		Great Western.		Liverpool.		Acadia.*	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
Length from Figure Head to Taffrail,.....	275	0	273	0	235	0	240	0	234	0	228	0
Length of Upper Deck,.....	245	0	243	0	0	0	0	0	212	0	206	0
Breadth within the Paddle-Boxes,.....	40	0	41	0	36	6	0	0	35	4	34	4
Breadth over all,.....	61	0	68	0	60	0	57	0	58	4	56	0
Depth of Hold,.....	27	0	30	0	22	0	20	0	23	3	22	6
Diameter of Paddle-Wheels,.....	31	0	30	0	0	0	0	0	28	0	28	0
Diameter of Engine Cylinder,.....	6	5½	7	6	0	0	0	0	6	1	6	0
Length of Stroke,.....	7	0	7	6	0	0	0	0	7	0	6	10
Power of Engines,.....	500 h. p.		600 h. p.		0 0		460 h. p.		450 h. p.			

* The three other North American Royal mail steam-ships Britannia, Caledonia, and Columbus, are of the same dimensions as the Acadia. (C. A.)

DESCRIPTION OF THE PLATES ON STEAM-ENGINE AND STEAM NAVIGATION.

Plate CCCCLXVIII. Figs. 1 and 2. These figures exhibit a front and side elevation of one of the simplest forms of the non-condensing steam-engine. Its principal parts are the cylinder A, the piston-rod P p, and connecting rod p K, acting directly upon the crank K X, and fly-wheel W W. Besides these there are only an eccentric and valve-rod x x x, and governor w w. Two columns and an entablature support one extremity of the crank axle, and give attachment to minor appendages. The other extremity of the axle rests on the wall of the building. To the columns is attached g g, a guide for the top of the piston-rod. The feed-pump f f f, is worked by an eccentric on the crank-shaft.

Figs. 3 and 4. The form of engine here exhibited, is of still greater mathematical simplicity than the last, although its mechanical arrangements are probably more intricate. In this engine no member intervenes between the piston-rod and the crank. A cross-head carried by the piston-rod, open in the centre, permits the crank-pin, in its circle of rotation, to oscillate freely on alternate sides of the piston; and being itself powerfully confined to motion in the vertical direction only, by the slides on the columns of the framing, the vertical motion of the piston-rod is precluded from the production of any other dynamical effect than the most direct of all possible conversions of rectilinear into rotatory motion. The cross-head is marked H H in the figure, the columns being marked m m. The other letters refer to the same parts as in the last figure.

Figs. 5 and 6. In these figures the high-pressure engine is represented in its most improved form for stationary purposes. It is analogous, in the arrangement of its principal parts, to the usual construction of Bolton and Watt's condensing-engine. A cast-iron base supporting six columns and an entablature, forms a framing upon which the parts of the engine are distributed, so as to form what is called a Portable Engine, being entirely independent of the building in which it may happen to be placed. At one extremity of the base is placed the cylinder A A, and at the other the crank-

axle X, and fly-wheel W W. The motion is transferred from the piston P p, through the great lever L L L, and connecting rod or crank-rod L K. The feed-pump f f is in this instance worked from the point m of the parallel motion, in the way generally adopted in condensing engines for working the air-pump, whose place in fact it here occupies. The valve is a short D-slide, worked by eccentric gear, x x x x. S is the steam-pipe. The education pipes E are seen descending on both sides of the valve-casing; they unite in a common chamber beneath the cylinder, whence a pipe conveys the educted steam to the chimney, or to serve some other purpose, as the case may be. The governor acts as in the previous case. This drawing is taken from the form of engine manufactured by Messrs Caird and Company.

Figs. 7 and 8 is a form of the upright condensing engine manufactured by Messrs Carmichael of Dundee, and successfully applied by them to various purposes. It is compact and has been found to work well.

The cylinder A A is placed upon the floor, and on either side of it stands a cast-iron column. These columns are hollow and are used as steam-pipes, S S S S, to convey the steam to the jacket of the cylinder, from which it finds its way into the valve-chest D. On the top of the columns is a cross-beam sustaining the crank axle, and the columns support guides m m m m, on which, by means of wheels g g, and a cross-head g p g, the piston-rod P p is maintained in its vertical position, so that the connecting rod p K is directly attached to the crank-pin K. The air-pump G is worked from the crank-shaft by means of a second crank or bend, and an eccentric x x works directly the slide valve; f f is the feed-pump for the boiler, worked directly from the air-pump cross-head; w w w w is the governor, with its appendages; C is the condenser; N the cold well.

Plate CCCCLXIX. In fig. 1. of this plate we have given a sectional elevation of a land-engine of twenty-five inch cylinder and five feet stroke. In fig. 2. we have given its horizontal section at the level of the base of the cylinder, and in the remaining figures the details of its

different parts. In figs. 1 and 2 AA is the cylinder, P the piston, Pp the piston rod, Bb the parallel motion, LLL the great lever. The pillow blocks Ll, in which the centre of the great lever works, rest on the spring beam UU, whose ends are secured to the walls of the building in the manner shown on the next plate. The centre of the spring beam is sustained by the columns VV and their entablature *u*, which crosses the building and has its ends secured to the walls like those of the spring beams. At the other end of the great lever are the connecting rod LK, the crank KX, and fly-wheel WW. Returning to the cylinder we have, DD the slide-valves and their casing; dd the packing ports. The valve-casing terminates below in EE the eduction-pipe leading into the condenser C. G is the air-pump, F the place of the foot-valve, *h* the air-pump piston-rod. The condenser and air-pump with their appendages are placed in the cold well N. M is the hot well into which the contents of the air-pump are discharged, and from which the hot water pump *m* draws its supply by the pipe *m'*. The pipe *oo* leads from the hot water pump for the supply of the boiler. The cold well is supplied from the cold water pump *n* by the pipe *n'*. The rods for working the hot and cold water pumps hang from a stud at either side of the lever at *m*. The governor *ww* is supported on a bracket *tt*, which bridges across the main shaft. The influence of the governor is conveyed to the throttle-valve by the levers and connecting rods *www*. The valves are worked by the eccentric *xxx*. *ff* is the eccentric shaft which carries the gab-lever *f'* on which the eccentric rod acts; it also carries the levers for working the side rods of the valves, the levers which carry the counterbalance weight, and the socket for the starting lever. The small pillars TT, which surround the cylinder, are surmounted by an entablature which serves as a support for a gangway round the cylinder.

The remaining figures on the plate represent in detail the different parts of the engine which we have just described, separated from each other, in order more clearly to exhibit their construction. Figs. A A' *a a'* show the details of the cylinder. In A A' is shown the upper and lower ports of the cylinder at 1 and 2, and the steam port at 3. In A', 4 is the cylinder cover, and 5 the stuffing box. *a* is a horizontal section of the cylinder, and *a'* a plan of the cylinder cover.

Figs. DD' dd' show the slide-valve casing; D a front view, D' a side view. 1 and 1 are the packing ports, 2 and 2 the packing-port covers, 3 the eduction-pipe, *d* the cover of the slide-valve casing, 4 its stuffing-box, *d'* a section of the casing. Figs. C, G, F, show a side elevation of the condenser, foot-valve, and air-pump; C, G, F, a section of these; and *c, g, f*, a plan of them. 1 is the cover of the foot-valve, 2 and 3 a section and front view of the valve. Fig. L shows a side view of the great lever, L 1 a top view, and L 2 a transverse section through the centre of it. Figs. KK' show a front view and section of the crank. Figs. XXx show a side view, an end view, and a plan, of the crank shaft pillow block. Figs. l, l1, l2, show a side view, an end view, and a plan of the pillow block for the main centre of the great lever. Figs. mm' show a vertical and horizontal section of the hot water pump, and figs. nn' of the cold water pump. Figs. B 1, 2, 3 are the details of the main links of the parallel motion; b 4, 5, 6, 7, 8 details of its air-pump links; 9, 10, 11, 12 side and top views of its radius and parallel bars. 13, 14 is the clutch for the top of piston-rod; 15, 16, gudgeon and clutch for the top of air-pump rod; 17, 18, top and side views of the ring gudgeon to which the parallel rods are attached; P piston-rod, H air-pump piston-rod, *h* air-pump rod, *gg* cold water pump-rod and piston-rod, and *g'g'* hot water pump-rod and piston-rod;

x the eccentric, WW, 1, 2, 3, 4 details of the fly wheel, O main centre or gudgeon for the great lever. PP 1 plan and section of the piston, *w w'* 1, 2, 3, 4, 5 details of the governor, *w* the spindle, *w'* the slide, 1 1 the radius arms to which the balls 5 5 are attached, 2 2 the radius arms which cause the balls to act on the sliding collar *w'*, 3 and 4 the stay for confining the motion of the balls. *t* 1 2 is the slide-valve rod and side rods, *t* 3 is the slide-valve cross-head, R R' a side and front view of the connecting rod.

Plate CCCCLXX exhibits a Sectional Elevation of a Condensing Engine. This description of house engine is the design of Mr M'Naught of Glasgow, and has been extensively applied by him to cotton, silk, and saw-mills. The principal peculiarity in its structure is the arrangement by which no further masonry is required for its foundation than the building in which it stands, the usual cold well being dispensed with, and the whole structure connected by cast-iron beams with the walls of the house. The cylinder AA is attached immediately to TT, the cast-iron beams of the floor, which are deeply bedded in the wall at T and T, and rests directly upon the large vessel C, which forms the condenser, and is supported likewise by beams YY, which are bedded in the walls. The condensation is effected by injection alone, without the usual accompaniment of a cold well around the condenser, an appendage that may safely be regarded as by no means indispensable to the practical perfection of the vacuum—when the vessel itself is formed with few joints. The transverse beams of the buildings are supported by two pillars directly under the centre of the great lever LLL, so as to support the main centre L; and the crank-axle X and the axis Z of the fly-wheel W, are supported on UU, another beam of cast iron.

The steam enters the house through the pipe SS, passes round the cylinder to SS, around the long slide-valve DD, being confined to the middle of it by the valve packing *hh*, and after performing its duty in the cylinder, passes out at EEE into the condenser C, where it is finally condensed into water. Hence it is drawn off at the foot-valve F by the piston H of the air-pump G, and delivered by the discharge-valve M into N, the hot well. The slide-valve DD is worked by the eccentric gear *xxx* and the rod *dD* through a moveable stuffing-box *dx*.

Plates CCCCLXXI, CCCCLXXII. These plates represent the high-pressure engines which are employed to work the inclined plane at the Liverpool station on the Liverpool and Manchester Railway. They are beautiful and in many respects highly judicious; they are the work of Messrs Mather, Dixon & Co., Liverpool.

WWW, Plate CCCCLXXII, is the great wheel which works the rope that draws the railway train up the inclined plane; the rope is contained in a groove in the edge of the wheel. A clutch *kk* connects or disconnects the crank-axle XXX with the wheel WW; the cranks KX, KX, KX are placed at right angles, so that when one is on the centre the other is at the furthest distance from it. *Kk*, the connecting rod, hangs down from LL, the ends of the levers. The centre of the side levers, IV., rests on a truss at no greater height than three feet above the floor of the engine-room. *Lp* is a side rod by which the levers are united to the cross-head *rpr*. The steam in this instance comes about a quarter of a mile from the boilers to the cylinders AA by the steam-pipe SSS. Fig. 2 is a section of the steam-valves and cylinder. The valves DD are short D-slides, surrounded by steam, and by the underside of the valves the escape takes place through the space E; *dD* is the valve-rod moved by the usual valve-gear *xxx*. The eccentric *xxx*, Plate CCCCLXXI, is placed on a long shaft from the

Steam Na- crank-axle at X, which shaft is also employed to work the governor-balls *ww*. The whole foundations are solid red sandstone rock, in which excavations are made for the shafts and ropes.

Plates CCCCLXXIII, CCCCLXXIV, CCCCLXXV. This very beautiful pair of engines was constructed by Mr Fairbairn of Manchester; and they are the property of Messrs Bailey and Co. of Staley Bridge, near Manchester. They are employed to drive a cotton-mill, and possess many excellent adaptations to this purpose.

These engines are of a similar form to those employed in large steam-vessels, and will serve very well to conduct the student from the common to the marine engine. The working beam or great lever LLL is, as it were, split in two, one of the halves being placed on each side of the engine, but united at the middle by a large gudgeon or main-centre, LL, and at the one end by a cross-head, *LpL*, and side rods, RL and RL, and at the other end by a cross-tail of similar form, and the connecting rod KL, which turns the crank KX. The moving mass is thus placed lower, and the whole rendered more compact, than the common house-engine.

This double marine engine is reckoned preferable in the manufacture of cotton to an engine of the common kind. The double engine gives a considerable degree of uniformity to the velocity produced; and the approximation to uniformity is rendered still more perfect by the short stroke, in which the variations of force recur at shorter intervals than with a long stroke. A striking peculiarity in this pair of engines is the large fly-wheel, WWW, formed of toothed segments, which receives the moving force of both engines, and gives it out directly, and with a high velocity, to the mill-shafts, YY. Not only is the requisite speed of revolution attained very readily and quickly by this means, but the momentum of the wheel is immediately conveyed to the shaft, instead of passing through a series of wheel and axle work. The durability and excellence of this arrangement are unquestionable.

The section, fig. 1, plate CCCCLXXIV, shows the details of many of the parts. The steam-pipe SSS from the boiler conducts the steam into a space SS, forming a jacket round the cylinder AA. The piston P has metallic rings on its periphery as packing; U and V, the upper and lower steam-ports, are wholly formed in the cover and bottom plate of the cylinder, and are closed and opened alternately by two short D-slides in two separate valve-chests above and below. The steam enters the upper chest from the jacket at S, where the throttle valve is inserted, and passes through the valve. The packing on the back of the valve is screwed down from above by a vertical spindle, and the eduction takes place through E by a hollow vertical column on one side of the valve-chest, while the steam passes down to the lower port through another column. The condenser C is a single casting, placed immediately below the valve-chest, and is entered by the injection pipe *cc* at *c*, of which the aperture is regulated by a slide-valve and vertical spindle ending in a screw. F is the foot-valve, governing the communication between the condenser and air-pump G; H is the air-pump piston, with common clack-valves; and M is the delivery-valve, opening outwards into the hot well. The waste-pipe is immediately below M; and the feed-pump and pipe *f* are in the masonry below the lever, so as to draw the feed-water from the waste-pipe.

The valves DD receive motion by an apparatus somewhat peculiar. A stud in the crank-pin K carries round a small radius rod *xx* on an axis, concentric with the crank; a smaller crank on this axis or shaft has a length equal to half the throw of the valve, or equal to that which would be given to the usual eccentric, and by a bar *xx* similar to the eccentric rod, the valve is moved by

this lesser crank, just as by an eccentric. This gearing has the advantage of lightness and precision. *mmm* are the usual links of the parallel motion; *d* is a counterpoise to the weight of the valve, *ww* are the weights of the governor.

Plate CCCCLXXVI. This is one of that class called the rotatory steam-engine; a class comprehending many varieties, of which we hear much and see but little. The engine is here given as an illustration of this very unsuccessful class of engines, by one of its least exceptionable examples. It has actually been in use for some years, being frequently employed to turn the machinery of a large establishment. We have seen it working smoothly and well. Yet we have not been able to recognize in it any reason for giving it an equality, much less a preference, in comparison with the common engine. It can be reversed in the same way as a common engine. It was invented by Mr Yule of Glasgow, by whom it was patented, and is still in the works of Thomas Edington, Esq., at Glasgow.

SSS is a double steam-pipe, either branch of which may be employed according as the engine is to go forward or backward. AA is the cylinder firmly fixed on a stone foundation, and in its centre is an axis XX, upon one side of which and eccentric to the cylinder is an inner cylinder or barrel turned quite true, and fixed to revolve with the axis X, and so to form the piston P, which is to receive and give out the force of the steam. RR furnishes the *point d'appui*, the surface of reaction, which resists the force of the steam and forms a fixed obstacle. It is a flat slide or sluice, (see fig. 5,) resting on the barrel piston P, and maintained by guides always in a vertical position. It passes into the cylinder through a rectangular stuffing box, and is raised and depressed by a small eccentric pin *xx*, so as to remain always upon the surface of the piston drum. All the working surfaces are rendered steam-tight by metallic packings. EEE is the eduction passage into the condenser or the open air, DD are slide-valves to be reversed when the engine is to go backwards. On the revolving axis of the piston X are toothed wheels, *gg*, working other two, *gg*, which have a common axis *zz*, carrying a fly-wheel, and driving the machinery to be worked by the engine. Fig. 6. shows the ports at DD. Fig. 7 shows the guides of the slide RR.

Plates CCCCLXXVII, CCCCLXXVIII, CCCCLXXIX exhibit views of a pair of beautiful marine engines, constructed by Mr Napier, for the four British and North American royal mail steam-ships Britannia, Acadia, Caledonia, and Columbia, plying between Liverpool, Halifax, (Nova Scotia) and Boston, (U. S.) The following are the general dimensions of the vessel and engines.

	Ft.	in.
Length from figure-head to taffrail,	228	
Length of keel and fore-rake,	206	
Breadth of beam between paddles,	34	6
Depth of hold,	22	6
Diameter of paddle-wheel,	28	
Length of floats,	26	
Diameter of cylinder,	6	
Length of stroke,	6	10

The power of the engines is about 240 horse power. The paddle shafts make 16 revolutions per minute. The tonnage of the vessel by the old law is about 1200 tons.

Plate CCCCLXXVII is a side elevation of one of the engines.

Plate CCCCLXXVIII is the elevation of the crank end of the engines, and Plate CCCCLXXIX the elevation of the cylinder end. By an inspection of these engravings it will be seen, that the parts of the engines are sus-

Steam Na-
vigation.

tained by an elegant and rigid Gothic framing, rendering them, notwithstanding the ponderosity of their different parts, entirely independent of the vessel on which they are placed. AA are the cylinders, B the slide-valve casing, C the condenser, D the hot well and air-vessel placed on the top of the condenser. E the air-pump, FF the feed-pumps. The moving parts of the engine are as follow:—K the cylinder piston-rod, I the cross-head, H the cylinder side rods descending to the great side levers GGG. Connected with the parts last described are the radius rods of the parallel motion L, the motion side rod L', and the parallel motion shaft l, V the valve or weigh-shaft on which is fixed the valve lever W, whose other end is inserted into a clutch on the slide-valve link c. On either side of the centre of the great lever depends a side rod ff, to work the bilge and brine pumps, and to its extremity are attached the links of the cross-tail of the connecting rods, P the links, Q the cross-tail, R the connecting rod. To the upper end of the connecting rod is attached the crank S; T is the intermediate or crank-shaft, T'T' the paddle-wheel shafts. On the crank-shaft is placed the eccentric U; and uu is the eccentric rod working the eccentric gab-lever v on the valve or weigh-shaft t t'. Y y y the expansion valve apparatus, h h escape valves at top and bottom of cylinders, X paddle wheels, k lever for starting the engines, 1 1 steam-pipes, 2 2 waste water pipes from hot well, 3 double force-pump for filling boilers, extinguishing fires, and washing decks, 4 4, engine beams, 5 5 5 5 midship section of vessel, 6 6 thick planks checked in upon and bolted through the timbers thus:—

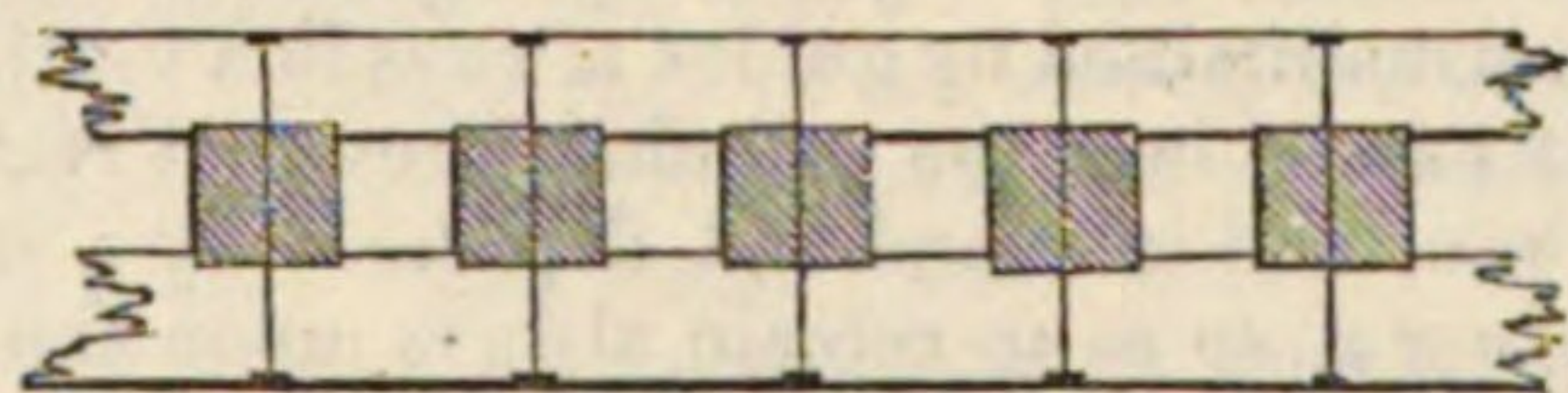


Plate CCCCLXXX. Side and end elevation of one of the engines of her Majesty's mail packet, Urgent, and also of the Actæon, built by Messrs Caird and Company of Greenock. The Urgent plies between Liverpool and Dublin; the Actæon between Liverpool and Glasgow. Both vessels have been very successful: they are swift boats, and consume a small amount of fuel. Their general dimensions are here noted.

	Urgent.	Actæon.
	Ft. in.	Ft. in.
Length of keel and fore-rake,	172 1	171
Breadth within paddle space,	26	25 10
Depth of hold,	17 5	17 3
Diameter of paddle-wheel,	24 6	
Length of floats, which in the Urgent are of Galloway's patent, in 3 breadths of about 9 inches each,	8 10	
Diameter of cylinder,	5 2	5 2
Length of stroke,	5 9	5 9

The power of each of the engines is 140 horse power. The paddle-shaft makes about twenty revolutions per minute. The tonnage of the Urgent, by the old law, is 562 $\frac{3}{4}$ —of the Actæon 551 $\frac{3}{4}$. A A is the cylinder, C the condenser, E the air-pump, H the cylinder side rods, I the cylinder cross-head, B the valve-casing, W the valve lever, W W the back balance, G G G the side levers, P the cross-tail links, Q the cross-tail, R the connecting rod, S the crank, U the eccentric, N the air-pump side rods, M the air-pump cross-head.

Plates CCCCLXXXI, CCCCLXXXII, CCCCLXXXIII, represent the engines of the Achilles, also built by Messrs Caird and Company, to ply between Liverpool and Glasgow. Plates CCCCLXXXI, CCCCLXXXII, show the two side elevations of one of the engines; and plate CCCCLXXXIII a

section of the vessel to a lesser scale, with the engines, Steam Navigation. paddle-wheels, &c., *in situ*. The arrangement of the framing of these engines is highly beautiful. The entablature supported by the columns, uniting both engines in one design, gives massiness of appearance, as well as great strength to the structure. In plate CCCCLXXXII is seen the apparatus for working the engines expansively. On the crank-axle T is placed a series of cams, t t t, which act upon the roller of the expansion-valve tumbler. Y y y are the expansion-valve connecting rods and levers. Z is the valve-chest, and the valve is of the kind called equilibrium valves, or crown valves. The other parts are A the cylinder, B the valve-chest, C the condenser, D the hot well, E the air-pump, F the feed and bilge pumps, G G the great lever, G' its main gudgeon, H the cylinder side rods, I the cross-head, K the piston-rod, L L the parallel motion, M the air-pump cross-head, N the air-pump side rods, O the air-pump piston-rod, P the connecting rod cross-tail links, Q the cross-tail, R the connecting rod, S the crank, U the eccentric pulley or cam, u u u the eccentric rod, V the valve-shaft, W W the valve-lever and counter balance lever.

Plates CCCCLXXXIV, CCCCLXXXV, CCCCLXXXVI. The engines exhibited in these plates are a pair of 110 horse power each, constructed by Messrs Fawcett, Preston & Co. of Liverpool.

Plate CCCCLXXXIV shows the side elevation of one of these engines. Plate CCCCLXXXV shows the elevation of the crank end of both engines; and plate CCCCLXXXVI the cylinder end of the engines, drawn to a somewhat smaller scale. The letters refer to the same parts as in the engines already described, and it is unnecessary here to repeat the description.

Plate CCCCLXXXVII. In this plate is given a representation of a single marine engine of 65 horse power, with a stroke of four feet. Fig. 1 is a side elevation; fig. 2 a plan or bird's-eye view; fig. 3 an elevation of the cylinder end; and fig. 4 an elevation of the crank end. The same letters indicate the same parts as in the former figures.

Plate CCCCLXXXVIII, fig. 1. is an end view, and fig. 2 a side view, of a double towing-engine of forty-five horse power and three feet six inches' stroke. The most striking peculiarity of this engine is, that the paddle-wheel shaft is separate from the crank-shaft, and driven by it through the intervention of toothed wheels. T is the cranks haft, with its spur wheel driving the spur wheel of the paddle-shaft T'. The other letters refer to the same parts as before.

Plate CCCCLXXXIX. In this plate are represented two engines of direct connexion, constructed by Messrs Tod and M'Gregor, Glasgow.

In figs. 1 and 2 of this plate, the crank S of the engine is placed directly above the cylinder A; the piston-rod K carries a cross-head I, which is guided to move in the vertical direction by two cross guides gg, one at each extremity, whose ends slide upon the vertical pillars pp, which sustain the framing for the support of the crank-axle. From each end of the piston cross-head depends a side rod HH, whose lower extremity, together with the ends of the side rods PP, which depend from the cross-tail Q of the connecting rod R, are attached to the end of a side lever GG. To the opposite end of the side levers are attached the side rods N of the air-pump, and on either side of its centre the side rods of the feed and bilge pumps F. The parts not already described are aa the slide-valve, C the condenser, E the air-pump, S the crank, U the eccentric, and uu u the eccentric rod and valve-gear.

In the engine represented in figs. 3 and 4, the pis-

Steam Na- ton-rod K terminates in a triangular frame III, from the
vigation. apex of which the connecting rod R descends to the
crank S; and to the extremities of its base are attached
the piston-rods OO of the air-pumps EE, which are in
this case two in number, and situated one on each side of
the cylinder. The triangular frame III is confined to
move in a vertical direction, by its cross-head *gg* being
guided in the slide *pp*. The remaining parts are, A the
cylinder, CC the condensers, *aa* the valve-chest, F the
feed-pumps, worked by an eccentric *ff*; Uu the eccentric
and valve-gear, and *eeee* the framing of the engine.

Plate ccccx. Fig. 1 of this plate is a side-eleva-
tion, and fig. 2 an elevation of the cylinder end, of a pair

of marine engines constructed by Messrs Seaward of the Steam Na-
Canal Ironworks, Limehouse, for H. M. steam-frigates vigation.
Gorgon, Cyclops, Prometheus, and Electo. These en-
gines are of a peculiar construction; the crank, as in the
engines of the last plate, being directly above the cylin-
der, the connecting rod only intervening between it and
the piston-rod. They are of the class of the vibrating
pillar-engines, the pillar which supports the beam turn-
ing upon a centre at its lower end. A is the cylinder,
B the valve-chest, C the condenser, E the air-pump, K
the piston-rod, R the connecting rod, S the crank, GGG
the beam, *g* the vibrating pillar, L the radius-rod, N
the air-pump side rod, M the air-pump cross-head.

STEEL.—As good iron is the basis of good steel, all
that has been said under the articles IRON and SMELTING
in reference to the sources and means of procuring that
metal in a state of purity, may be advantageously refer-
red to as a preliminary to the present.

Steel is a carburet of iron, with probably a slight
mixture of other substances which are more or less
essential to its perfection, and certainly in most cases
with some alloy which is not essential, but which, on
the contrary, is to some extent injurious. This descrip-
tion would equally apply to cast-iron, which differs
from steel as to its ingredients principally in the
quantity of carbon, cast-iron having sometimes one-
fifteenth part, and good steel seldom more than one
two-hundredth part of that substance. The difference
between the proportions of the carbon does little, how-
ever, to explain the difference between cast-iron and
steel; for, while the condition of cast-iron is retained, it
is found that diminishing the quantity of carbon renders
it still less like good steel. It appears, in short, that the
good qualities of steel—and they are very various—
depend upon circumstances partly chemical and partly
mechanical, which have hitherto defied analysis. It is not
even precisely known whether the union of the iron and
carbon is a chemical or mechanical union: perhaps it may
be partly one and partly the other, for reasons which
will presently be given.

In consequence of this ignorance as to what constitutes
the essential qualities of good steel, the processes by
which favourable results have been obtained have in nearly
all cases been empirical, and in many instances have been
real or pretended secrets. The processes are of a nature
to forbid any very nice calculations, and they are liable to
great and unappreciable modifications in the execution.
For example, steel being, as before stated, a carburet
of iron, and having generally a slight admixture of oxyde
of iron, must be subject to many incalculable changes
during its successive exposures to violent heat in contact
with carbonaceous fuel and atmospheric air. Moreover,
the hammering, on which many of its good properties
depend, is obviously an operation which cannot be meted
out with very scrupulous nicety, and is besides liable to
be very much influenced by the temperature of the metal
and by the direction of the blows in reference to the
mechanical structure of the mass.

A good practical essay on steel, it is therefore evi-
dent, would consist in an exceedingly minute detail of
the actual operations applied to a certain description
of ore, or to a known specimen of manufactured iron,
which, with certain sorts of fuel, had been found uniformly
to produce steel peculiarly adapted to certain purposes.
Such an essay would form a volume, and it would still

convey imperfectly what it professed to teach, because
in all the processes there are certain stages of the con-
version whose advent is judged of by the experienced
eye and hand of the skilful workman, from symptoms
which can be explained only to the sight and touch.
Here we only propose to describe, in very general
terms, some of the principal processes, so as to convey
a knowledge of the *theory* of steel-making without pro-
fessing to give the actual practice. We must pre-
mise, that the destination of the steel is of great im-
portance in estimating even the theory of those pro-
cesses, as may be well supposed when it is recollected
that a lancet will fracture almost like glass, while a
bricklayer's trowel is required to cut the most refractory
lump of semi-vitrified clay in the shape of a brick. These
two instruments are perhaps at the extremities of the
scale, the perfect hardness and brittleness of the lancet
contrasting with the extraordinary toughness and tena-
city of the trowel.

It was at one time, indeed, thought so difficult to com-
bine these last-mentioned qualities with sufficient hard-
ness to sever a good stock-brick, that trowels were
made of a plate of iron to supply the toughness, and an
edge of steel to give the hardness. Even at the present
time it is supposed that the peculiar qualities of certain
sword-blades result from their being combinations of
hard steel with soft tenacious iron fibre; and that the
variegated or *damashed* surface of such blades is owing to
the different appearances presented by the iron and steel.
By some this effect has been supposed to result from
chemical changes acting partially upon the original car-
buret, depositing the carbon more profusely in some parts
of the iron than in others. It may arise, as already
hinted, from some portions of the carburet being in a
chemical, and others only in a mechanical state of union.
According to other authorities, the structure in question
has been manufactured expressly by binding up portions
of soft iron wire with ingots of steel, and hammering the
whole into a mass at a high temperature. Such a process
will, it is known, produce very similar appearances.
Whatever be the truth in regard to the sword-blades,
certain combinations of iron and steel in parallel laminæ
are advantageously employed for some purposes. The
carpenter's *plane-iron*, for example, consists of a very
thin hard steel face on an iron back; because this instru-
ment requires to unite a cutting edge nearly equal to that
of the lancet with a tenacity which shall encounter unin-
jured the hardest knots; a trial almost as severe as that
applied to the trowel.

One great cause of the uncertainty and obscurity attend-
ing the practice of steel-making, is the importance of the
hammering or other mechanical parts of the operation. If

Steel.

the distinction between good and bad steel were principally chemical, the production of the former would long since have been rendered easy and determinate. How little this is the case may be inferred from the fact, that the elaborate series of experiments conducted a few years since by Dr Faraday and Mr Stodart have scarcely added a new fact to the science of steel-making; while, on the other hand, the immense value of mechanical action is shown, among numerous instances, by the increased strength of *drawn* iron wire as compared with *rolled* iron of equal size, a difference amounting sometimes to sixty or seventy per cent.

The remarkable qualities of the trowels for which a Mr. Walby was celebrated about forty years since, resulted in a great measure, if not entirely, from good and rapid hammering at a moderate temperature. The object of hammering being to condense the steel, it is evident that when at a white heat, in a state approaching to fusion, the mass is so plastic, it yields so freely, that hammering is perfectly inoperative, except to change the external form; while, on the other hand, if the mass be cold, it is so unsusceptible of what may be called intestinal movement among its particles that the most violent hammering can do little more than dislocate portions of the surface, which will accordingly crack or scale off. Between these extremes a medium may be found, and was, we believe, found by Mr Walby. His hammering was principally performed at a low cherry-red heat; and, by means of a peculiar and ingeniously mounted hammer of considerable weight, he was enabled to do all that was required before the temperature was sensibly lowered. But, as we are informed, he did more than this. It is quite certain that in hammering any mass, and especially in a thin plate, the central cannot be under the same circumstances as the exterior portions. Not only will the centre retain its heat somewhat longer, but, what is of more consequence, the tendency of the central portions to spread laterally under the hammer, is resisted by the marginal parts; while these latter not being so protected by a belt, spread freely, and perhaps separate into detached pieces. If, for example, a circular disc of steel at a low temperature were violently beaten under a flat hammer, it would be very much condensed in the middle, while the circumference would gradually separate, showing radial splits or cracks. The most perfect way to condense a circular disc of metal would obviously be to confine it in a very strongly defended cavity, whose walls should prevent all lateral spreading, and thus the full effect of each blow would be felt in condensation. Such a process is, however, inapplicable to trowel making, and perhaps to all other purposes except the striking of medals, where we see it employed; but Mr Walby obtained nearly all the effect of such an arrangement by forging each trowel considerably larger than it was ultimately intended to be, and cutting off about an inch of superfluous metal after the hammering was completed; cutting off, that is to say, the wall which had acted to restrain the spreading of the central portion of the blade, and which had probably become loose and spongy itself for want of such restraint, thus leaving only the *close* compact metal in the finished trowel.

Having thus endeavoured to direct the reader's attention to some of the qualities demanded in steel, and to the causes which affect their production, we shall briefly describe some of the operations.

Steel is most frequently made from rolled bars of *good*, by which we mean *pure* iron. To communicate to these bars the desired quantity of carbon, they are formed into bundles, and are placed in a large stove or furnace alternating with layers of carbon, (hard-wood charcoal is preferred,) and a high temperature being maintained

for a week or ten days, the iron gradually absorbs the required quantity of carbon, and becomes converted into steel. The completeness of this conversion is judged of from time to time by the examination of certain of the bars, which are so disposed as to be accessible for this purpose. If the carbon has not penetrated to the centre of the metal, this will be evident on breaking the bar transversely, as the section will exhibit a colour in the centre different from that near the surface: it will show what the workmen call a pith. Towards the end of the process, the watching requires to be skilful and constant, because, if the absorption of carbon becomes very excessive, the metal may be rendered so fusible as suddenly to melt; and though this would be of little consequence in a sound crucible, it would be attended with great loss in a large stove or hearth. The surface of the bars becomes so nearly in this condition that it is always blistered by the escape or rarefaction of air or gas from the interior of the metal; and hence bars so prepared have acquired the name of blister or blistered steel. The process itself is called cementation.

The bars thus prepared do not differ very greatly from cast-iron, except in the smaller quantity of carbon which they contain, and in their freedom from impurities. They have somewhat more malleability and tenacity than cast-iron, but not so much as is imparted to that substance during its conversion to bar-iron, and which must now, except for very coarse purposes, be communicated to these bars of cementation—without, however, depriving them of their carbon. With this view the bars so prepared are broken up into short lengths, are made into bundles, heated almost to a white heat, hammered, welded together, re-broken and re-hammered till they are reduced as nearly as possible to a compact homogeneous mass of greater specific gravity than in their former state. In all these weldings, care is required to preserve the surfaces clean and unoxidized, as upon this depends the perfect union of the two surfaces.

This care is dispensed with in the processes for making cast-steel, the nature of which has been already indicated in describing that of cementation. The pure iron and a certain proportion of carbon are fused together in a crucible, and being cast into ingots, these are treated somewhat like the bundles of the cemented bars. They are hammered at a high temperature till they are rendered malleable and dense, and till a certain portion of the carbon is displaced, that substance being generally in excess. Various modes of applying the carbon have been proposed; but it is very difficult to determine in the abstract which of these is the best. One mode of application is, by the introduction of a stream of gas. Cast-steel is free from the defects which are liable to attend the imperfect welding of the bars, and is likely to supersede all others for the finer purposes of cutlery. It requires, however, the most skilful manipulation as the point of sufficient fusion is reached, and this must be performed under the most severe exposure to heat; so severe as to demand that the workmen should be protected, by clothing of wetted sackcloth, from the joint effects of the opened furnace and the glowing crucible. This combination of skill and severe labour secures high wages, and enhances the price of the article.

The experiments of Faraday and Stodart, before alluded to, were undertaken not so much to improve the mode of manufacture as to determine the effect of various alloys; it having been inferred, partly from the condensation which frequently accompanies chemical unions, and partly from the examination of certain specimens of steel which were known to possess good qualities, that a small portion of foreign matter might be beneficially introduced. With this view, alloys

Steel.

Steel.

of steel with gold, silver, platinum, and many other metals, in various proportions and combinations, were made, without however producing any very definite results. One of the best was a mixture of 500 parts of steel with one part of silver. While the silver was in this small proportion, it appeared to diffuse itself equally throughout the mass, and the union appeared to be chemical. No remarkable increase of specific gravity accompanied the union; and the opinion formed at the time, that the steel was improved by the addition, is beginning to be shaken. It is worth mentioning, that if the quantity of silver much exceeded the five-hundredth part, the excess was distributed in small distinct fibrous masses, in such a manner as to unfit the steel for most purposes of utility.

Having by any of the means now mentioned manufactured a good steel or a good alloy, it is found to have acquired a property on which its great value in the arts entirely depends: we mean the property of becoming very hard when *suddenly* cooled from a high temperature. If heated to whiteness, and then plunged into water, instead of the malleable tenacious substance which had been produced under the welding hammers, it has become nearly as hard as a diamond and as brittle as glass. The sudden cooling from a white heat would, however, be found to have damaged considerably the compactness of the steel; and practically it is known, that the lower the temperature on which the sudden cooling can be made to act with effect, the better will be the quality of the metal. It is also supposed that the lower the temperature at which the steel is manufactured—that is to say, hammered into compactness and malleability—the lower will be the temperature necessary to give it hardness. When all these points have been determined to the greatest exactness, there remains another consideration which has been well pointed out by a recent writer on the subject. Since the perfection of every steel instrument depends upon its receiving a hardness very exactly proportioned to its intended use, and as the subsequent operations will equally affect every part of the hardened steel, it is most important that the hardening be equal in every part, in order that the hardness of the whole, when reduced, shall be equal. If then the heated steel, at the moment of its plunge into the water, be in some parts coated with an oxyde of iron while in other parts it is clean, the rapidity of the cooling in the various parts will be so different as to affect seriously the uniformity of the result. In this way, among others, we can understand how it happens that one part of a razor or other instrument shall be much harder than another. To avoid this inequality, it has been proposed that the instrument shall be perfectly cleansed upon a stone previously to hardening, and then heated with the utmost care to prevent the formation, or at least the unequal formation, of oxyde upon the surface. Various opinions and practices prevail as to the mode of cooling. Besides water at various temperatures, saline solutions, mercury, and a current of air, have been suggested; but it is doubtful whether any of them is preferable to water at a moderate temperature.

The steel having now been made indefinitely hard, too hard generally for any practical purposes, it requires to be tempered or softened down more or less, according to the nature and uses of the intended instrument. This is done by the application of a moderate heat, varying from 430° to 600° of Fahrenheit; the higher temperatures softening the metal proportionally more than the lower.

Formerly the heat applied in tempering was judged of by the colour assumed by the steel, a portion being

always ground clean, to enable the operator to observe exactly when the required shade of colour was obtained. These colours, it may be stated, are produced by the action of the oxygen in the air upon the heated metal; and though their indications are sufficiently accurate for most purposes, it has been found desirable in some cases to substitute a fusible metallic bath, by which a regulated temperature may with certainty be communicated.

The following table, showing the temperatures according to Fahrenheit which correspond with various colours, was drawn up by the late Mr Stodart:—

1. Very pale straw yellow,.....	430°
2. A shade of darker yellow,.....	450
3. Darker straw yellow,.....	470
4. Still darker straw yellow,.....	490
5. A browner yellow,.....	500
6. Yellow slightly tinged with purple,.....	520
7. Light purple,.....	530
8. Dark purple,.....	550
9. Deep blue,.....	570
10. Paler blue,.....	590
11. Still paler blue,.....	610
12. Still paler blue, with a tinge of green,...	630

When the hardened steel is heated only within the limits here specified, it matters not how it is cooled; the softening or tempering equally takes place, and is proportioned to the temperature. The knowledge of the proper degrees of heat or colour adapted to various instruments, is obtained wholly by experience. The following table, extracted from the work before mentioned, is perhaps as accurate as any:—

INSTRUMENTS.	COLOURS.	TEMPERATURES.
1. Razors and instruments with a stout back and fine edge,	Straw colour.	430° to 450°
2. Scalpels and penknives,		
3. Scissors and small shears,	Full yellow.	470°
4. Pocket and pruning knives,	Brown yellow.	490°
5. Watch-springs, swords, &c.	First tinge of purple.	510°
	Purple.	550° to 560°

After the operation of tempering, nothing is required but the final grinding, fashioning, and polishing of the article, which it is not here requisite to discuss. (C. K.)

STEEL-YARD. See WEIGHING-MACHINES.

STEELE, SIR RICHARD, was born in Dublin about the year 1676. One branch of the family was possessed of a considerable estate in the county of Wexford. His father, a counsellor at law in Dublin, was private secretary to James, Duke of Ormond; but he was of English extraction; and his son, while very young, being carried to London, he put him to school at the Charter-house, whence he was removed to Merton College in Oxford. He left the university without taking any degree, in the full resolution to enter into the army. This step was highly displeasing to his friends; but the ardour of his passion for a military life rendered him deaf to any other proposal. Not being able to procure a better station, he entered as a private gentleman in the horse guards, notwithstanding he thus lost the succession to his Irish estate. However, as he had a flow of good nature, a generous openness and frankness of spirit, and a sparkling vivacity of wit, these qualities rendered him the delight of the soldiery, and procured him an ensign's commission in the guards. In the mean time, as he had made choice of a profession

Steele.

Steele.

which set him free from all the ordinary restraints in youth, he spared not to indulge his inclinations in the wildest excesses. Yet his gayeties and revels did not pass without some cool hours of reflection; it was in these that he drew up his little treatise entitled *The Christian Hero*, with a design, if we may believe himself, to be a check upon his passions. For this purpose it had lain for some time by him, when he printed it in 1701, with a dedication to Lord Cutts, who had not only appointed him his private secretary, but procured for him a company in Lord Lucas's regiment of fusiliers.

During the same year he brought out his comedy, called *The Funeral, or Grief à la Mode*. This play procured him the notice of King William, who resolved to give him some essential marks of his favour; and though, upon that prince's death, his hopes were disappointed, yet, in the beginning of Queen Anne's reign, he was appointed to the profitable place of gazetteer. This post he owed to the friendship of Lord Halifax and the Earl of Sunderland, to whom he had been recommended by his schoolfellow Mr Addison. That gentleman also lent him a helping hand in promoting the comedy called *The Tender Husband*, which was acted in 1704 with great success. But his next play, *The Lying Lover*, had a very different fate. Upon this rebuff from the stage, he turned the same humorous current into another channel; and early in the year 1709, he began to publish the *Tatler*; which admirable paper was undertaken in concert with Dr Swift. His reputation was perfectly established by this work; and, during the course of it, he was made a commissioner of the stamp-duties in 1710. Upon the change of the ministry the same year, he joined the Duke of Marlborough, who had several years entertained a friendship for him; and upon his Grace's dismissal from all employments in 1711, Mr Steele addressed a letter of thanks to him for the services which he had rendered to his country. As, however, he still continued to hold his place in the stamp-office under the new administration, he wisely declined the discussion of political subjects; and, adhering more closely to Addison, he dropped the *Tatler*, and afterwards, by the assistance chiefly of that steady friend, he carried on the same plan, much improved, under the title of the *Spectator*. The success of this paper was equal to that of the former; and, before the close of it, he was thus encouraged to proceed upon the same design in the character of the *Guardian*. This was opened in the beginning of the year 1713, and was laid down in October the same year. But in the course of it his thoughts took a stronger turn to politics: he engaged with great warmth against the ministry; and being determined to prosecute his views by procuring a seat in the House of Commons, he immediately removed all the obstacles that stood in his way. For that purpose he took care to prevent a forcible dismissal from his post in the stamp-office, by a timely resignation of it to the Earl of Oxford; and at the same time gave up a pension, which had hitherto been paid to him by the Queen as a servant to the late Prince George of Denmark. He now wrote the famous *Guardian* upon the demolition of Dunkirk. It was published August 7, 1713; and the parliament being dissolved next day, the *Guardian* was soon followed by several other warm political tracts against the administration. Upon the meeting of the new parliament, Steele having been returned a member for the borough of Stockbridge in Hampshire, took his seat accordingly in the House of Commons; but was expelled in the course of a few days, for writing the close of the paper called the *Englishman*, and one of his political pieces entitled the *Crisis*. Pre-

Steele.

sently after his expulsion, he published proposals for writing the history of the Duke of Marlborough. At the same time he also wrote the *Spinster*; and, in opposition to the *Examiner*, he set up a paper called the *Reader*, and continued publishing several other papers and tracts in the same spirit till the death of the queen. As a reward for these services, he was immediately taken into favour by her successor to the throne, King George I.; was appointed surveyor of the royal stables at Hampton Court, and governor of the royal company of comedians was put into the commission of the peace for the county of Middlesex, and in 1715 received the honour of knighthood. In the first parliament of that king, he was chosen member for Boroughbridge in Yorkshire; and, after the suppression of the rebellion in the north, was appointed one of the commissioners of the forfeited estates in Scotland. In 1718, he buried his second wife, who had brought him a handsome fortune with a good estate in Wales; but neither this, nor the ample addition lately made to his income, was sufficient to answer his demands. The thoughtless vivacity of his spirit often reduced him to little shifts of wit for its support; and the project of the fish-pool this year, owed its birth chiefly to the projector's necessities. This vessel was intended to carry fish alive, and without wasting, to any part of the kingdom; but notwithstanding all his towering hopes, the scheme proved very ruinous to him; for after he had been at an immense expence in contriving and building his vessel, besides the charge of the patent, which he had procured, it turned out upon trial to be a mere project. His plan was to bring salmon alive from the coast of Ireland; but these fish, though supplied by this contrivance with a continual stream of water while at sea, yet uneasy at their confinement, shattered themselves to pieces against the sides of the pool; so that when they were brought to market they were worth very little.

The following year he opposed the remarkable peerage bill in the House of Commons; and, during the course of this opposition to the court, his license for acting plays was revoked, and his patent rendered ineffectual at the instance of the Lord Chamberlain. He did his utmost to prevent so great a loss; and finding every direct avenue of approach to his royal master effectually barred against him by his powerful adversary, he had recourse to the method of applying to the public, in hopes that his complaints would reach the ears of his sovereign, though in an indirect course, by that channel. In this spirit he formed the plan of a periodical paper, to be published twice a-week, under the title of the *Theatre*; the first number of which appeared on the 2d of January 1719-20. In the mean time, the misfortune of being out of favour at court, like other misfortunes, drew after it a train of more. During the course of this paper, in which he had assumed the feigned name of *Sir John Edgar*, he was outrageously attacked by Mr Dennis, the noted critic, in a very abusive pamphlet, entitled *The Character and Conduct of Sir John Edgar*. To this insult he made a proper reply in the *Theatre*.

While he was struggling with all his might to save himself from ruin, he found time to turn his pen against the mischievous South Sea scheme, which had nearly brought the nation to ruin in 1720; and the next year he was restored to his office and authority in the playhouse in Drury-Lane. Of this it was not long before he made an additional advantage, by bringing his celebrated comedy called the *Conscious Lovers* upon that stage, where it was acted with prodigious success; so that the receipt there must have been very considerable, besides the profits accruing by the sale of the copy, and a purse

Steerage
||
Steevens.

of £500 given to him by the king, to whom he dedicated it. Yet notwithstanding these ample supplies, about the year following, being reduced to the utmost extremity, he sold his share in the playhouse; and soon after commenced a lawsuit with the managers, which in 1726, was decided against him. Having now again, for the last time, brought himself by the most heedless profusion into a desperate condition, he was rendered altogether incapable of retrieving the loss, by being seized with a paralytic disorder, which greatly impaired his understanding. In these unhappy circumstances, he retired to his seat at Llanganor near Caermarthen in Wales, where he died on the 21st of September 1729, and, according to his own desire, was privately interred in the church of Caermarthen. Among his papers were found the manuscripts of two plays, one called *The Gentlemen*, founded upon the Eunuch of Terence, and the other entitled *The School of Action*, both nearly finished.

Sir Richard was a man of undissembled and extensive benevolence, a friend to the friendless, and, as far as his circumstances would permit, the father of every orphan. His works are chaste and manly. He was a stranger to the most distant appearance of envy or malevolence; never jealous of any man's growing reputation; and so far from arrogating any praise to himself from his conjunction with Mr Addison, that he was the first who desired him to distinguish his papers. His great fault was want of economy; and it has been said of him, he was certainly the most agreeable and the most innocent rake that ever trode the rounds of dissipation.

STEERAGE, on board a ship, that part of the ship next below the quarter-deck, before the bulk-head of the great cabin, where the steersman stands in most ships of war.

STEERING, in *Navigation*, see SEAMANSHIP.

STEEVENS, GEORGE, the most successful of all the editors and commentators of Shakspeare, was born in the year 1735. We know nothing respecting his parents; but they appear to have been in affluent circumstances. He received the rudiments of his education at Kingston-upon-Thames, and had Gibbon the historian for a companion at that school. From hence he went to Eton, and in a few years was admitted a fellow commoner of King's College, Cambridge; but no mention is made of his peculiar course of studies. It appears however that he had little relish for the mathematics, which lead at Cambridge to academical honours. On the first establishment of the Essex militia, he accepted of a commission; but he spent the concluding years of his life in almost total seclusion from the world, seldom mingling with society but in the shops of booksellers, in the Shakspeare gallery, or in the morning conversations of Sir Joseph Banks.

Although not an original writer, we cannot in justice refuse him a place among the literary characters of the age, when we consider the works which he illustrated, and the learning, sagacity, taste, and general knowledge which he brought to the task. With a versatility of talents, he was eminent both by his pen and his pencil; but his chief excellence lay in his critical knowledge of an author's text; and the best specimen of his abilities is his edition of Shakspeare, in which he has left every competitor far behind him. He had studied the age of Shakspeare, and employed his persevering industry in becoming acquainted with the writings, manners, and laws of that period, as well as the provincial peculiarities, whether of language or customs, which prevailed in different parts of the kingdom; but more particularly in those where Shakspeare passed the early

years of his life. He was continually increasing this store of knowledge, by the acquisition of the obsolete publications of a former age, which he spared no expense to obtain. His critical sagacity and observation were constantly employed in calling forth the hidden meanings of the dramatic bard, and of course enlarging the display of his beauties. This advantage is apparent from his last edition of Shakspeare, which contains so large a portion of new, interesting, and accumulated instruction. In preparing it for the press, he gave an instance of activity and perseverance without example. To this work he exclusively devoted a period of eighteen months, during which he left his house at Hampstead every morning at one o'clock, going to his friend Mr Isaac Reed's chambers in Barnard's Inn, without any consideration of the weather or the season, and there he found a sheet of the Shakspeare letterpress ready for correction. Thus, while the printers slept, the editor was awake, by which means he completed, in less than twenty months, his splendid edition of Shakspeare in fifteen volumes octavo; a labour almost incredible, and by which the energy and persevering powers of his mind were fully proved.

He probably rested satisfied with being a commentator from the particular habits of his life, and his devotion to the name of Shakspeare. But at the same time he was a classical scholar of a respectable order, and well acquainted with the polite literature of Europe. He studied ancient and modern history, and particularly that of his own country. His genius was strong and original, his wit abundant, his imagination of every colour; and his sentiments were enlivened with the most brilliant expressions. His eloquence was logical and animated; his descriptions were so true to nature, his figures so curiously selected, and so happily grouped, that he might be regarded as a speaking Hogarth. He scattered his wit and his humour too freely around him, and they were not lost for want of gathering.

Mr Steevens had a very handsome fortune, which he managed with discretion. His generosity was equal to his fortune; and though not profuse of his money to sturdy beggars, few persons distributed with more liberality to truly deserving objects. He possessed all the graces of outward accomplishment, at a period when civility and politeness were characteristics of a gentleman. He bequeathed his valuable Shakspeare, illustrated with about 1500 prints, to Earl Spencer; his Hogarth, perfect, with the exception of one or two pieces, to Mr Windham; and his corrected copy of Shakspeare, with 200 guineas, to his friend Mr Reed. He died in the month of January 1800, about sixty-five years of age.

STEGANOGRAPHY, the art of secret writing, or of writing in ciphers, known only to the persons corresponding.

STELLIONATE, in the civil law, a kind of crime, committed by a fraudulent bargain, where one of the parties sells a thing for what it is not; as if he sells an estate for his own which belongs to another, or conveys a thing as free and clear which is already engaged to another, or puts off copper for gold, &c.

STEMPHILA, a word used by the ancients to express the husks of grapes, or the remains of the pressings of wine. The same word is also used by some to express the remaining mass of the olives, after the oil is pressed out.

STEMPYLITES, a name given by the ancients to a sort of wine pressed hard from the husks.

STEMPLES, in mining, cross bars of wood in the shafts which are sunk to mines,

Stegano-
graphy
||
Stemples.

Steno-
graphy.

STENOGRAPHY.¹ The art of stenography, or short writing, was known and practised by most of the ancient civilized nations. The Egyptians, who at an early period were distinguished for learning, at first expressed their words by a delineation of figures called *hieroglyphics*. A more concise mode of writing seems to have been afterwards introduced, in which only a part of the symbol or picture was drawn. This answered the purpose of short-hand in some degree. After them the Hebrews, the Greeks, and the Romans, adopted different methods of abbreviating their words and sentences, suited to their respective languages. The initials, the finals, or radicals, often served for whole words; and various combinations of these sometimes formed a sentence. Arbitrary marks were likewise employed to determine the meaning, and to assist legibility; and it seems probable that every writer and every author of antiquity had some peculiar method of abbreviation, calculated to facilitate the expression of his own sentiments, and intelligible only to himself. It is also probable that some might by these means take down the heads of a discourse or oration; but few, very few, it is presumed, could have followed a speaker through all the meanders of rhetoric, and, in a manner legible even to themselves, could have noted with precision every syllable as it dropt from his mouth. To arrive at such consummate perfection in the art was reserved for more modern times, and is still an acquisition by no means general.

In every language of Europe, till about the close of the sixteenth century, the Roman plan of abbreviating (viz. substituting the initials or radicals, with the help of arbitraries, for words) appears to have been employed. Till then no regular alphabet had been invented expressly for stenography, when an English gentleman of the name of Willis invented and published one.² His plan was soon improved, or at least altered. One alteration succeeded another; and at intervals, for a series of years past, some men of ingenuity and application have composed and published systems of stenography, and doubtless have themselves reaped all the advantages that attend it. But among the various methods which have been proposed, and the different plans which have been adopted by individuals, none has yet appeared fortunate enough to gain general approbation, or proved sufficiently simple, clear, and concise, to be universally studied and practised. Some systems are replete with unmeaning symbols, perplexing arbitraries, and ill-judged contractions; which render them so difficult to be attained by a common capacity, or ordinary application, that it is not to be wondered at if they have sunk into neglect, and are now no longer known. Other systems, by being too prolix, by containing a multiplicity of characters, and those characters not simple or easily remembered, become ineffectual to the purpose of expedition, and are only superior in obscurity to a common hand. Some, again, not only reject all arbitraries and contractions, but even prepositions and terminations; which last, if not too lavishly employed and badly devised, highly contribute to promote both expedition and legibility; and though they reduce their characters to fewer than can possibly express the various modifications of sound, yet they make nearly one half of them complex. In the disposition of the vowels there is the greatest perplexity in most systems. A dot is sometimes substituted for all the vowels indiscriminately, and the judg-

ment is left to determine which letter out of six any dot is intended to express; or a minute space is allotted them; so that unless they be arranged with mathematical precision, they cannot be distinguished from one another; but such a minute attention is inconsistent with the nature of shorthand, which should teach us to write down in a short time, as well as in small bounds, what we wish to preserve of what we hear. Nor is the plan of lifting the pen and putting the next consonant in the vowel's place, in the middle of words, less liable to objections; or that of representing all the vowels by distinct characters, being obviously ill calculated for facility and despatch, and consequently inadmissible into any useful system.

It is to be confessed, that the person who first proposed the omission of vowels in the middle of words,³ which it is obvious are not wanted, and invented letters which could be connected as in a running hand without lifting the pen in the middle of the word, made a real improvement on the works of his predecessors. But, in fine, most systems, either in their plan or execution, labour under some capital defect, attended with circumstances highly discouraging to the learner, and which in a great measure defeat the end of their invention, by being too complicated to be learned with ease and remembered with accuracy, or to be practised with the expedition which is requisite; and so difficult to be deciphered, that a man can scarcely read what he has just written. To obviate these defects, to provide against prolixity and conciseness, which might occasion obscurity, to exhibit a system founded on the simplest principles, which might be easily learned and read, and yet be capable of the utmost expedition, were the motives that gave rise to the present attempt.

This method will be found different from any yet published, and superior to all in the disposition of the vowels and the facility of arranging them; the confusion in placing which seems to detract from the merit of the best performances on the subject; and it may without ostentation be affirmed, that characters simpler in their form, and more perfect in their union, have not been applied to the art of stenography. As well as it could be determined, the simplest characters are appropriated to the letters most usually employed; indeed, as far as possible, those which are complex have been rejected; but as it was an object always kept in view that the writing should be on a line, a few are admitted into the alphabet for that reason. The characters for the double and triple consonants are the easiest that could be invented, consistent with perspicuity; for care has been taken to provide against all obscurity which might arise by adopting letters too similar in their formation; and with respect to the prepositions and terminations, those which occur most frequently are expressed by the simplest characters, which will be found perfectly easy in their application. The arbitraries are few in number, and the arbitrary abbreviations, as they are entirely from the letters of the alphabet, and chosen from some thousands of words in common use, will well repay the learner for an hour's trouble in committing them to memory.

The last section lays down a scheme of abbreviation, comprised in a few rules, perfectly easy to be understood and practised by proficients in this art; and we hope it will answer the expectation of the writer, and will be found free from the perplexity complained of in many systems

Steno-
graphy.

¹ The value of stenography is not unknown to the learned; and the care and success with which it has been lately cultivated in these kingdoms will, in all probability, soon render it an object of general attention. No one, however, appears to us to have simplified and improved the art so much as Dr Mavor, author of *Universal Stenography*.

² Mr Locke says, a regular method of short writing seems to be known and practised only in Britain. This is not now the case; and indeed there is no reason to doubt whether characters may not be invented to express the various sounds or letters employed in any language, either ancient or modern.

³ Mr Byrom rejected vowels entirely in the middle of words, as others before him had only done partially. Without critically examining the executive part of his performance, which is very defective, it must be owned that it is above the reach of human ingenuity to exceed his general plan, which for ever must be the basis of every future rational system.

Steno-
graphy.

where abbreviation is admitted. The principal rules are new, are so easy, so extensive in their use, and so consistent with expedition and legibility, if applied with judgment, that they alone might suffice. The learner is however advised by no means to adopt any of them till experience has convinced him that they may be used without error, or injury to legibility. All abbreviating rules are suited to those only who have made some progress in the stenographic art; for although they certainly promote expedition in a wonderful manner, and afford the greatest ease to a proficient, yet a learner, as expedition is not his first, though his ultimate view, should admit of nothing that in the least renders the reading difficult.

The general principles of stenography.

II. The English alphabet consists of twenty-six letters; six of which are vowels, *a, e, i, o, u, and y*; and the other twenty consonants, *b, c, d, f, g, h, j, k, l, m, n, p, q, r, s, t, v, w, x, and z*. This alphabet, as is observed by the best grammarians that have written on the language, is both defective and redundant in expressing the various modifications of sound.¹ Custom or prejudice has assigned some letters a place, when others would with much more propriety express the same sound; and to this may be added, that several letters, sometimes in one word, seem to be admitted for no other reason than to perplex a young beginner or a foreigner, as an obstruction to true pronunciation, and to add to the apparent length of the word, when they are entirely quiescent and useless. That this is the genius of the orthography of our language, must be perceived by the most superficial observer; but no modern tongue is absolutely free from the same exceptions. In particular, the French has a great number of dormant letters, which, it is obvious, render the pronunciation more difficult and perplexing to learners. In this respect, the Latin and Greek claim a just superiority over the modern tongues. In them no confusion or doubt can arise from the manner of spelling; and the reader can scarcely be wrong, unless in quantity, in sounding all the letters that he sees.

But as it is neither our business nor our intention to propose a mode of spelling different from that in common use, when applied to printing or long-hand writing (since several innovators in orthography have fallen into contempt, and their plans have been only preserved as beacons to warn others of the folly of endeavouring to subvert established principles²), we shall only observe, that in stenography, where the most expeditious and concise method is the best, if consistent with perspicuity, the following simple rules are studiously to be regarded and practised.

Rules for the consonants.

1. All quiescent consonants in words are to be dropped, and the orthography to be directed only by the pronunciation; which being known to all, will render this art attainable by those who cannot spell with precision in long-hand.

2. When the absence of consonants, not entirely dormant, can be easily known, they may often be omitted without the least obscurity.

3. Two or sometimes more consonants may, to promote greater expedition, be exchanged for a single one of nearly similar sound; and no ambiguity as to the meaning ensue.³

4. When two consonants of the same kind or same sound come together, without any vowel between them, only one is to be expressed; but if a vowel or vowels intervene, both are to be written: only observe, if they are perpendicular, horizontal, or oblique lines, they must only be drawn a size longer than usual; and characters with loops must have the size of their heads doubled.

Might is to be written *mit*, fight *fit*, machine *mashin*, enough, *enuf*, laugh *laf*, prophet *profet*, physics *fisiks*,

through *thro'*, foreign *foren*, sovereign *soveren*, psalm *sam*, receipt *reset*, write *rite*, wright *rit*, island *iland*, knavery *navery*, temptation *temtation*, knife *nife*, stick *stik*, thigh *thi*, honour *onour*, indictment *inditement*, acquaint *aquaint*, chaos *kaos*, &c.

Strength *strenth*, length *lenth*, friendship *frenship*, connect *conek*, commandment *comanment*, conjunct *conjunt*, humble *humle*, lumber *lumer*, slumber *slumer*, number *numer*, exemplary *exemlary*, &c.

Rocks *rox*, acts *aks* or *ax*, facts *faks* or *fax*, districts *dis-triks* or *distrix*, affects *afeks* or *afex*, afflicts *afliks* or *aflix*, conquer *konkr*, &c.

Letter *leter*, little *litle*, command *comand*, error *eror*, terror *teror*, &c. But in *remember*, *moment*, *sister*, and such like words, where two consonants of the same name have an intervening vowel, both of them must be written.

These four rules, with their examples, being carefully considered by the learner, will leave him in no doubt concerning the disposition and management of the consonants in this scheme of short writing; we shall therefore proceed to lay down rules for the application of the vowels with ease and expedition.

1. Vowels, being only simple articulate sounds, though they are the connectives of consonants, and employed in every word and every syllable, are not necessary to be inserted in the middle of words; because the consonants, if fully pronounced, with the assistance of connection, will always discover the meaning of a word, and make the writing perfectly legible.

2. If a vowel is not strongly accented in the incipient syllable of a word, or if it is mute in the final, it is likewise to be omitted; because the sound of the incipient vowel is often implied in that of the first consonant, which will consequently supply its place.

3. But if the vowel constitutes the first or last syllable of a word, or is strongly accented at its beginning or end, that vowel is continually to be written.

4. If a word begins or ends with two or more vowels though separated, or when there is a coalition of vowels, as in diphthongs and triphthongs, only one of them is to be expressed, which must be that which agrees best with the pronunciation.

5. In monosyllables, if they begin or end with a vowel, it is always to be inserted, unless the vowel be *e* mute at the end of a word.

Such are the general principles of this art; in vindication and support of which it will be needless to offer any arguments, when it is considered that brevity and expedition are the chief objects, if consistent with legibility; and the subsequent specimens in the orthography recommended will, we hope, be sufficient to show that there is no real deficiency in the last-mentioned particular.

He who md us mst be etnrl, grt, nd mnptnt. It is or Specimen
dty, as rsnl bngs, to srv, lv, nd oby hm.—A mn tht wd avd of the mode
blm, shd be srkmspk in al hs axns, nd ndvr wth al hs mt to of spelling
pls evry bdy.—I wd nt frm any knxns wth a mn who hd no in steno-
rgrd fr hmslf; nthr wd I blv a mn who hd ons tld me a li. graphy.
—Onr is of al thngs the mst dfklt to prsrv ntrnshd; nd whn
ons mpchd, lk the chstty of a wmn, nvr shns wth its wntd
lstr.—Wth gd mnrs, kmplsns, nd an esy plt adrs, mny mk
a fgr in the wrl, whs mnl abltys wd skrsly hv rsd thm abv
the rnk of a ftmn.—Idlms is the prnt of a thsnd msfrtns,
wch ar nvr flt by the ndstrs: it is a pn nd a pnshmnt of
itslf, and brngs wnt nd bgry in its trn.—Vrtu is the first
thng tht shd be rgrdd; it is a rwrdd of itslf; mks a man
rspktbl hr, nd wl mk hm etrnly hpy hrfr.—Prd is a mst
prnss psn, wch yt ws plntd by hvn in ur ntr, to rs ur emlsn

¹ Lowth's Grammar. Priestley's Grammar. Sheridan's Lectures on Elocution.

² By this rule likewise *q* and *v* in the middle of words, but never in the beginning, may be exchanged for *k* and *f*, when they admit of an easier connecting with the following character, or will make the writing appear neater.

³ Preface to Johnson's Dictionary.

Steno-
graphy.

to imtt grt nd wrthy krktrs or axns, to xt in us a sl fr wht is rt nd gst, and a ldbl ndgnsn gnst oprsrs nd wrkrs of ny kind of nkyty; in shrt, to mk us st a prpr vlu upn urslvs, nd dsps a wrthls flo, hu evr xlted. Ths fr prd is a vrtu, nd my gstly be kld a grtns of sl. Bt prd, lk othr psns, gnrlly fxs upn rng obgks, or is apld in rng prprsns. Hu kmn is it to se a rtch whm evry vs hs rndrd msrbl, nd evry fly kntmbl, vlng hmslf on hs hi brth, nd bstng ths ilstrs nsstrs, of whm he nhrts nthng bt the nm or ttl! nsstrs who, if thy nu hm, wd dsn thr dsndnt wth kntmt. But al prd of ths srt is fly, nd evr to be avdd.

III. As the whole of this art depends upon a regular method and a simple alphabet, we have not only endeavoured to establish the former on satisfactory principles, but have been careful to appropriate, according to the comparative frequency of their occurrence, such characters for the letters as, after repeated trials and alterations, were conceived to be the best adapted for despatch.

Stenogra-
phic alpha-
bet.
Plate
CCCCXC.

The stenographic alphabet consists of eighteen distinct characters (viz. two for the vowels and the rest for the consonants), taken from lines and semicircular curves; the formation and application of which we shall now explain, beginning with the vowels.

For the three first vowels, *a*, *e*, and *i*, a comma is appropriated in different positions; and for the other three, *o*, *u*, and *y*, a point. The comma and point, when applied to *a*, and *o*, are to be placed at the top of the next character; when for *e* and *u*, opposite to the middle; and when for *i* and *y*, at the bottom.

This arrangement of the vowels is the most simple and distinct that can easily be imagined. Places at the top, the middle, and the bottom of characters, which make three different positions, are as easily distinguished from one another as any three separate characters could be; and a comma is made with the same facility as a point.

Lines.

Simple lines may be drawn four different ways; perpendicular, horizontal, and with an angle of about forty-five degrees to the right and left. An ascending oblique line to the right, which will be perfectly distinct from the rest when joined to any other character, may likewise be admitted. These characters being the simplest in nature, are assigned to those five consonants which most frequently occur, viz. *l*, *r*, *t*, *c* hard or *k*, and *c* soft or *s*.

Circles.

Every circle may be divided with a perpendicular and horizontal line, so as to form likewise four distinct characters. These being the next to lines in the simplicity of their formation, we have appropriated them for *b*, *d*, *n*, and *m*.

Curves and
lines.

The characters expressing nine of the consonants are all perfectly distinct from one another; eight only remain which are needful, viz. *f*, *g* or *j*, *h*, *p*, *q*, *v*, *w*, and *x*; to find characters for which we must have recourse to mixed curves and lines. The characters which we have adopted are the simplest in nature after those already applied, admit of the easiest joining, and tend to preserve lineality and beauty in the writing.

It must be observed, that we have no character for *c* when it has a hard sound, as in *castle*; or soft, as in *city*; for it naturally takes the sound of *k* or *s*, which in all cases will be sufficient to supply its place.

R likewise is represented by the same character as *l*; only with this difference, *r* is written with an ascending stroke,¹ and *l* with a descending; which is always to be known from the manner of its union with the following character; but in a few monosyllables where *r* is the only consonant in the word, and consequently stands alone, it is to be made as is shown in the alphabet, for distinction's sake.

Z, as it is a letter seldom employed in the English language, and only a coarser and harder expression of *s*, must be supplied by *s* whenever it occurs; as for *Zedekiah* write *Sedekiah*, &c.

Steno-
graphy.

IV. The prepositions and terminations in this scheme are so simple, that the greatest benefit may be reaped from them, and very little trouble required to attain them; as the incipient letter or the incipient consonant of all the prepositions and of several of the terminations is used to express the whole. But in order to give every assistance, we have subjoined the following directions.

Rules for
preposi-
tions and
termina-
tions.
Plate

1. The preposition is always to be written without joining, yet so near as plainly to show what word it belongs to; and the best way is to observe the same order as if the whole was to be connected.

2. A preposition, though the same letters that constitute it may be met with in the middle or end of a word, is never to be used, because it would expose to obscurity.

3. Observe that the preposition *omni* is expressed by the vowel *o* in its proper position; and for *anti*, *anta*, *ante*, by the vowel *a*, which the radical part of the word will easily distinguish from being only simple vowels.

The first rule for the prepositions is to be observed for the terminations; and also the second, *mutatis mutandis*; except that whenever *sis*, *sus*, *sys*, *cious*, *tious*, and *ces* occur, they are to be expressed as directed in the fourth rule for the consonants, whether in the beginning, middle, or end of words.

4. The terminative character for *tion*, *sion*, *cion*, *cian*, *tian*, is to be expressed by a small circle joined to the nearest letter, and turned to the right; and the plurals *tions*, *cions*, *cians*, *tians*, by a dot on the same side.

5. The terminative character for *ing* is to be expressed likewise by a small circle, but drawn to the left hand; and its plural *ings* by a dot.²

6. The plural sign *s* is to be added to the terminative characters when necessary.

7. The separated terminations are never to be used but in polysyllables, or words of more syllables than one.

These rules duly observed will point out a method as concise and elegant as can be desired, for expressing the most frequent and longest prepositions and terminations in the English language. If it should be thought necessary to increase their number by the addition of others, it will be an easy matter for any one of the least discernment to do so, by proceeding on the principles before laid down.

V. Though a more concise method of writing, or more numerous abbreviations, may not be indispensably necessary, if the foregoing directions be practised for a considerable time, yet contractions will be found extremely useful and convenient to those who have attained a proper knowledge of the subject, and will lead to a greater degree of expedition, at the same time that they diminish the labour of writing. It has been observed in the introduction, that abbreviations are only to be employed by proficient in this art; because expedition is not the first, though the ultimate, object in view; and that an easy legibility is of the utmost consequence to the learner; which however cannot be preserved, if he adopts too soon those very rules which in time will afford him the greatest ease when applied with judgment.

Rules for
abbrevia-
tion.

The following short and practical rules will be found, we hope, fully adequate to every purpose for which they were intended, and are far superior in the facility of their application to any which we have seen.

1. The usual abbreviations in long-hand are always to

¹ The character for *h*, when lineality requires it, may be made from the bottom and inverted. And often *h* may be omitted entirely, or a vowel may be substituted in its stead, without any injury to legibility, it being rather a breathing than a letter.

² In horizontal characters, by the left hand is meant the top, and by the right the space below the letter. In all other characters the right and left positions will naturally be known.

Stentoro-
phonic
Tube
||
Stephanus.

be followed; as Mr for Master, M. D. for Doctor of Physic, and Abp. for Archbishop, &c.

2. Substantives, adjectives, verbs, and participles are to be expressed by their initial consonant with distinguishing marks, viz. a substantive must have a dot exactly over its initial consonant; an adjective must have a dot under it; a verb is to be expressed by a comma over its initial consonant; and a participle by a comma under.¹ These, being the four principal parts of speech, will be sufficient; and an adept will never be at a loss to know when he can with safety apply this rule to them.

3. To render the writing more legible, the last letter of the word may be joined to the first, and the proper mark applied.

4. The constituent or radical part of words, especially if they are long, will often serve for the whole or sometimes the first syllable: as we ought to moderate our *ex.* by our *circum.*; a man's *man.* commonly shape his *for.*

5. All long words without exception may have their prepositions or terminations expressed by the incipient consonant of such preposition or termination.

6. When there is a great dependence between the parts of a sentence, the initial letter will often suffice; as *L.* is the capital of Great *B.*; the eldest *S.* of the king of Great *B.* is styled prince of *W.* Every one, it is presumed, will allow this to be perfectly legible in long-hand; then why may it not in stenography?

7. The terminations *ness* and *less* may be omitted; as *faithfulness* is only to be written *faithful*; *forwardness*, *forward*; *heedless*, *heed*; *stubbornness*, *stubborn*, &c.

8. The second and third persons of verbs, ending in *eth* and *est*, may be expressed by *s*; as, he *loves*, thou *teaches*; instead of he *loveth*, thou *teachest*: or even without *s*; as, he *love*, &c.

9. Words may often be entirely omitted, and yet no ambiguity ensue; as, *In beginning God created heaven and earth*, for *In the beginning God created the heaven and the earth*.

10. When there is an immediate repetition of a sentence or word, a line is to be drawn under the sentence or word to be repeated; as, *Amen, Amen*, is to be written *Amen*; but if any words intervene before a word or sentence is to be repeated, the line must be drawn as before, and a Δ or mark of omission placed where the repetition should begin; as, *Is it just the innocent should be condemned* Δ *re-veiled*?

STENTOROPHONIC TUBE, a speaking trumpet; thus called from Stentor, a person mentioned by Homer.

STEP, in a ship, a block of wood fixed on the decks or bottom of a ship, and having a hole in its upper side, fitted to receive the heel of a mast or capstern. The steps of the main and fore masts of every ship rest upon the kelson, to which they are firmly secured by knees, bolts, or spike-nails. The step of the mizen-mast usually rests upon the lower deck.

STEPHANO, *St.*, a city of the province of Mazzara, in the island of Sicily. It stands on the sea-shore, in a situation rather unhealthy, on the declivity of Mount Quisquina, and at the distance of forty-eight miles from Palermo. It contains about 6000 inhabitants.

STEPHANOPHORUS, in *Antiquity*, the chief priest of Pallas, who presided over the rest. It was usual for every god to have a chief priest; that of Pallas was the Stephanophorus, and that of Hercules was called Dadouchus. Stephanophorus was also a priest who assisted the women in the celebration of the festival Thesmophoria.

STEPHANUS BYZANTINUS, a learned grammarian, who flourished about the close of the fifth century. He wrote

a large work, in which he made a great number of observations, borrowed from mythology and history, which showed the origin of cities and colonies; of which we have little remaining but an abridgement by Hermolaus the grammarian. Even in this state, it has been found a work of no inconsiderable value. It is alphabetically arranged, and bears the inscription Περὶ Πολέων, or "Concerning Cities." The first edition was printed by Aldus, Venet. 1502, fol. This was followed by an edition printed by the heirs of P. Junta, Florent. 1521, fol. The text received many emendations in the edition of Xylander, Basil. 1568, fol. All these editions contain the Greek text, without any Latin version. An edition, with a translation, and copious annotations, was published by Thomas de Pinedo, Amst. 1678, fol. Another edition, with a translation and a commentary, was prepared by Berkellius, and after his death was completed by J. Gronovius, Lugd. Bat. 1688, fol. Nor must we here omit the posthumous "Notæ et Castigationes" of Holstenius, Lugd. Bat. 1684, fol.

STEPHANUS, *Henry*, the founder of a most remarkable and meritorious family of printers, was born at Paris in the year 1470. The French name is Estienne, which is frequently transformed into the English *Stephens*, although the correct translation would be *Stephen*. He began the business of a printer about the year 1503. This is the date of Boethius's treatise on arithmetic, the first book that is known to have issued from his press. A great proportion of the books which he published were Latin. They are printed in the Roman letter, and are not inelegant, though some of them abound rather too much in contractions. He died about the year 1520, and left behind him three sons, Francis, Robert, and Charles. His widow married Simeon de Colines (*Colineus* in Latin), who thus got possession of Henry's printing-office, and continued the business till his death.

Of Francis, the eldest son, little more is known than that he carried on business along with Colineus, and that he died at Paris in 1550.

ROBERT STEPHANUS, the second son, was born at Paris in 1503. In his youth he made great proficiency in the Latin, Greek, and Hebrew languages, and at the age of nineteen had acquired so much knowledge that his step-father intrusted him with the management of his press. He soon afterwards began business himself, and married Perrete, the daughter of Jodocus Badius, a printer and an author. She was a woman of learning, and understood Latin, which indeed was the necessary consequence of her situation. Her husband always entertained a number of learned men as correctors of the press. Being foreigners, and of different nations, they made use of no other language but Latin; which Perrete being accustomed to hear, was able in a short time not only to understand, but even to speak with tolerable ease.

In 1531 he published his "Thesaurus Linguae Latinae;" a work of great labour, and of great value. The device which he exhibited in all his books was a tree branched, with a man looking upon it, and these words *Noli altum sapere*, to which he sometimes added *sed time*. In 1539, Francis I. made him his printer, and ordered a new set of elegant types to be founded for him. His frequent editions of the New Testament gave great offence to the doctors of the Sorbonne, who accused him of heresy for his annotations, and insisted upon the suppression of some of his books. Although Henry, the French king, in some measure protected him, the persecution of these divines rendered him so unhappy, not to mention the expense and loss of time which an almost constant attendance at court unavoidably occasioned, that in 1552 he abandoned his country and settled

¹ The dot or comma being placed thus will never occasion them to be mistaken for vowels, because they should always be on one side or other; whereas the mark for parts of speech may constantly be placed exactly over or under.

Stephanus. at Geneva. Here he embraced the Protestant religion, and thus justified in some measure the suspicions of his theological enemies. It has been affirmed by several writers that he carried along with him the royal types, and the moulds in which they were cast; but it is certain that he never afterwards made use of those types. Besides, is it possible that the author of so daring a theft could have been not only protected in Geneva, but even courted and honoured by the most eminent men of the age? Is it credible that such a crime could have been concealed for sixty years; or that Henry, the son and heir of the perpetrator, would have enjoyed the favour of the French king, if Robert Stephanus had acted such a shameful part? If he was burnt in effigy at Paris, it was not for theft, but for having renounced the popish faith. After his arrival at Geneva, he published an account of the dispute between him and the Paris divines, which does as much honour to his abilities as his *Thesaurus* does to his learning. He died in 1559, after a life of the most extraordinary industry. The books of which he was the editor were not fewer than 360. Many of them were ancient classics in different languages. Several were accompanied with annotations which he collected, and all of them were corrected by the collation of manuscripts. He was so anxious to obtain perfect accuracy, that he used to expose his proofs in public, and reward those who discovered a mistake. His books consequently were very correct. It is said that his New Testament, called *O Mirificam* (because the preface begins with these words), has not a single fault. It was Robert Stephanus who first divided the New Testament into verses, during a journey between Paris and Lyon. The advantages of this improvement are fully counterbalanced by its defects. It has destroyed the unity of the books, and induced many commentators to consider every verse as a distinct and independent aphorism. By his last will his estate was left exclusively to such of his children as should settle at Geneva. He left behind him three sons, Henry, Robert, and Francis.

CHARLES STEPHANUS, the third son of Henry, was, like the rest of his family, familiarly acquainted with the learned languages. This recommended him to Lazarus de Baif, who made him tutor to his son, and in 1540 carried him along with him to Germany. He studied medicine, and took his doctor's degree at Paris. He did not however forsake the profession of his family, but exercised it at Paris, where he became the editor of many books remarkable for neatness and elegance. He wrote above thirty treatises on different subjects, particularly on botany, anatomy, and history. Having been unsuccessful in business, he was imprisoned for debt in the Chatelet in 1561, and died there in 1564.

ROBERT STEPHANUS, the son of Robert the first of that name, did not accompany his father to Geneva, but continued to profess the Romish religion, and to reside at Paris. His letter was remarkably beautiful. He was made king's printer, and died about 1589. His brother Francis, who was also a printer, embraced the Protestant religion, and resided at Geneva.

HENRY STEPHANUS, the eldest brother, was born at Paris in 1528. He became the most learned and most celebrated of all his family. From a very early age he gave proofs of uncommon abilities, and displayed an ardent passion for knowledge. The *Medea* of Euripides, which he saw acted while at school, first kindled his love for poetry, and inspired him with the desire of acquiring the language in which that tragedy is written. He entreated his father not to condemn him to study Latin, which he already understood from conversation, but to initiate him at once in the knowledge of Greek. His father willingly acceded to his request; and Henry applied with such vigour, that in a short time he could repeat the *Medea* by heart. He afterwards studied Greek under Danesius, who

was tutor to the Dauphin, and finally heard the lectures of Stephanus Tusanus and Turnebus. At an early age he became eager to understand astrology, and accordingly attended a professor of that mysterious art; but he was not long in discovering its absurdity. At the age of nineteen he began his travels, which he undertook in order to examine foreign libraries, and to become acquainted with learned men. He spent two years in Italy, and returned into France completely master of Italian, and bringing along with him copies of several scarce authors, particularly a part of Anacreon, which previously was supposed to be lost. He found his father publishing an edition of the New Testament, to which he prefixed some Greek verses. Soon after, he visited England and the Netherlands, where he met with John Clement, an Englishman, to whom he was indebted for the remaining odes of Anacreon. During this journey he learned the Spanish language, which was very much spoken at that time in the Low Countries.

Whether Henry accompanied his father to Geneva, is uncertain: if he did, he must have returned immediately to France, for we find him soon after established at Paris, and publishing the odes of Anacreon. In 1554 he went to Rome, and thence to Naples. This journey was undertaken at the request, and in the service, of the French government. He was discovered, and would have been arrested as a spy, had he not by his address and skill in the language of the country been able to pass himself for a native of Italy. On his return to France, he assumed the title of printer to Ulric Fugger, a very rich and learned German nobleman, who allowed him a considerable pension.

In 1560 he married a relation, as is generally supposed, of Henry Scrimger, a Scottish scholar and civilian, with whom he was intimately acquainted. She was a woman, as he himself informs us, endowed with the noblest spirit and the most amiable disposition. Her death, which happened in 1586, brought on a disease that had twice attacked him before. It was a disgust at all those pursuits which had formerly charmed him, an aversion to reading and the sight of books. It was probably occasioned by too constant and severe an application to literary pursuits. In 1572 he published, in four vols. folio, his *Thesaurus Linguae Graecae*, one of the greatest works, perhaps, that ever was executed by one man, if we consider the wretched materials which more ancient dictionaries could furnish, the size and perfection of the work, and the immense labour and learning which must have been employed in the compilation. In 1573, he added *Glossaria duo, e situ vetustatis eruta*. This work had been carried on at a greater expense than he could well bear. He expected to be reimbursed by the sale of the book, but he was unfortunately disappointed. Scapula, one of his own correctors, extracted from it whatever he thought would be most serviceable to students, and published it beforehand in quarto. By this act of treachery Henry was reduced to poverty.

About this time he was much beloved by Henry III. of France, who treated him so kindly, and made him such flattering promises, that he resided frequently at court. But these promises were never fulfilled, owing to the civil wars which soon after distracted France, and the unfortunate death of Henry himself. During the remainder of his life, his situation was very unsettled. We find him sometimes at Paris, sometimes at Geneva, in Germany, and even in Hungary. He died at Lyon in 1598, at the age of seventy. His temper during the latter part of his life is represented as haughty and severe, owing probably to his disappointments. He was twice married, and by his first wife had a son and two daughters, one of whom was married to the learned Isaac Casaubon.

This most erudite printer was fond of poetry from his very infancy. It was his practice to compose verses on

Stephanus horseback, and even to write them, though he generally rode a very mettlesome steed. His Thesaurus was his great work, but he was also the author of many other treatises in the French and Latin languages. His poems are numerous. His "Apologie pour Herodote" is a very singular performance. It has been illustrated by the annotations of Duchat. The number of books which he published, though fewer than his father, was great, and they were superior in elegance to any thing which the world had then seen. A great proportion of them were Greek. He was the editor, however, of many Latin and even of some oriental writings. His Greek classics are remarkably correct; and many of his editions are accompanied by most learned notes. His Thesaurus still maintains an unrivalled reputation. An edition, with very ample additions, was recently published by Barker and Valpy; and another elaborate edition is now in progress at Paris.

PAUL STEPHANUS, the son of Henry, continued his father's profession at Geneva. He was a man of learning, executed translations of several books, and published a considerable number of the ancient classics; but his editions possess little of his father's elegance. He died in 1627, at the age of sixty, after selling his types to one Chouet, a printer. His son Antony, the last printer of the family, abandoned the Protestant religion, and returned to France, the country of his ancestors. He received letters of naturalization in 1612, and was made printer to the king; but managing his affairs ill, he was reduced to poverty, and obliged to retire into an hospital, where he died in 1674, miserable and blind, at the age of eighty.¹

STEPHEN'S ISLAND, in Torres Strait, north of Darnley's Island. Long. 143. E. Lat. 9. 0. S.

STEPHEN'S ISLANDS, two small islands in the Eastern Seas, the one about three miles long, and the other about six. The passage between them is three miles broad. Long. 138. 39. E. Lat. 0. 22. S.

STEPNEY, a parish of the county of Middlesex, in the hundred of Ossulton, adjoining to London, and forming one of the suburbs, or rather a part of the metropolis. It was very extensive, and comprehended the districts on the side of the Thames, and extending till it united with Hackney, but has been divided into the distinct parishes of Stratford, Whitechapel, Limehouse, Wapping, Shadwell, Ratcliff Highway, Spitalfields, and Bethnal Green. It is commonly said by seamen, that all children born at sea are parishioners of Stepney, and that all the colonies of England are part and parcel of this parish, so as to make it the largest in the world. The population of the present division, containing four hamlets, Mile End Old Town, Mile End New Town, Poplar with Blackwall, and Ratcliff, amounted in 1801 to 25,260, in 1811 to 37,199, in 1821 to 49,163, and in 1831 to 67,872.

STERCORARIANS, or **STERCORANISTÆ**, formed from *stercus*, "dung," a name which those of the Romish church anciently gave to such as held that the host was liable to digestion, and all its consequences, like other food.

STEREOGRAPHIC PROJECTION, is the projection of the circles of the sphere on the plane of some one great circle, the eye being placed in the pole of that circle.

STEREOMETER, an instrument invented in France for measuring the volume of a body, however irregular, without plunging it in any liquid.

STEREOMETRY, *Στερεομετρία*, formed of *στερεος*, *solid*, and *μετρον*, *measure*, that part of geometry which teaches how to measure solid bodies, *i. e.* to find the solidity or solid contents of bodies; as globes, cylinders, cubes, vessels, ships, &c.

STEREOTOMY, formed from *στερεος*, and *τομή*, *section*, Stereotomy the art or act of cutting solids, or making sections thereof; as walls and other membranes in the profiles of architecture.

STEREOTYPE PRINTING, a method of printing, which was introduced into this country by William Ged of Edinburgh, before the middle of the eighteenth century. See **PRINTING**.

STERLING, an epithet by which genuine English money is distinguished. It is unnecessary to mention the various conjectures of antiquaries about the origin and meaning of this appellation. The most probable opinion seems to be this, that some artists from Germany, who were called *Esterlings*, from the situation of their country, had been employed in fabricating our money, which consisted chiefly of silver pennies; and that from them the penny was called an *esterling*, and our money *esterling* or *sterling* money.

STERN, the posterior part of a ship. The stern is terminated above by the taffarel, and below by the counters; it is limited on the sides by the quarter-pieces, and the intermediate space comprehends the galleries and windows of the different cabins.

STERN-Fast, a rope used to confine the stern of a ship or boat to any wharf or jetty head, &c.

STERN-Most, in sea language, usually denotes that part of a fleet of ships which is in the rear, or farthest a-stern, as opposed to headmost.

STERN-Post, a long straight piece of timber erected on the extremity of the keel, to sustain the rudder and terminate the ship behind.

STERN-Sheets, that part of a boat which is contained between the stern and the aftmost or hindmost seat of the rowers. It is generally furnished with benches to accommodate the passengers.

STERNE, **LAURENCE**, an eccentric writer of fiction, has left behind him a sketch of the principal events of his life, and some particulars of his family history. From that outline it appears that he was born at Clonmell, in the south of Ireland, on the 24th November 1713. His father was a lieutenant in the army, and grandson of Dr Richard Sterne, archbishop of York. When his son was about eight years of age, Lieutenant Sterne placed him at a school in Halifax, to which town he had been conducted by his professional duties. That officer died in 1731, and in the following year, young Sterne, by the bounty of a relation and namesake of his own, was transferred from the school of Halifax to Jesus College, Cambridge.

Having completed his studies at the university, he proceeded to York; and his uncle, Dr Jacques Sterne, prebendary of Durham, and canon residentiary and precentor of York, procured him the living of Sutton, and afterwards a prebend at York. At York he formed an acquaintance with the lady who afterwards became his wife, under circumstances sufficiently romantic. From a friend of hers he obtained the living of Stillington, but continued for twenty years to reside at Sutton, relieving the burden of his double charge, as he informs us, "by books, painting, fiddling, and shooting." In the library of Shelton Castle, the residence of his friend and relation, John Hall Stevenson, author of a licentious production, entitled *Crazy Tales*, Sterne found among the dross of antiquity many a brilliant gem, which he transferred without scruple to his own pages. In this stolen garb he cut a most imposing figure, until Dr Ferriar of Manchester, twenty years after the death of the celebrated plagiarist, restored the pilfered trappings to the rightful owners.²

In 1759, Sterne produced the first two volumes of *Tris-*

¹ Almeloveen de Vitis Stephanorum. Amst. 1683, 8vo. Maittaire, *Historia Stephanorum*. Lond. 1709, 8vo. *Biographie Universelle*, tom. xiii. p. 386.

² See Dr Ferriar's *Illustrations of Sterne*. Lond. 1798, 8vo.

Sternomantis
||
Stettin.

tram Shandy, which procured him both money and reputation. In these volumes there was abundance of matter which every one could relish; and what was unintelligible was thought profound. Much ingenious speculation was squandered upon the black leaves and marbled pages, which were long contemplated with wonder, before they were discovered to mean nothing. "The republic of dark authors," says Swift, "have been peculiarly happy in the variety, as well as extent, of their reputation."

Before this period, Sterne had only printed two sermons. The two volumes of Tristram Shandy were succeeded by two volumes of Sermons. In 1761 appeared the third and fourth volumes of the novel, and the fifth and sixth in the year following. The seventh and eighth volumes were published in 1765; but these monstrous births had by that time ceased to please. Four volumes of Sermons were produced in 1766; and in 1767, these were followed by the ninth and last volume of Tristram Shandy. In 1768 Sterne returned from Italy, whither he had repaired in the hopes of finding relief for a consumptive complaint with which he had long been afflicted. He only survived to prepare for the press the first part of his Sentimental Journey, which was published in 1768. In the month of March of that year he expired at his lodgings in Bond Street, surrounded by strangers; a mode of death which he considered as most desirable.

The English writer to whom the author of Tristram Shandy is most indebted for his matter is Burton; and his manner bears some resemblance to the capricious, whimsical, and digressive Tale of a Tub. He even mimics Swift in sneering at "the great Dryden;" but in the writings of his prototype he might have found many things infinitely more worthy of imitation. In order to make room for his pathos, however, he eschewed the misanthropy of the dean of St Patrick's, and set up for a lover of his species, to which character his claims were less than equivocal, for his philanthropy did not extend so far as to his own mother. That sensibility is worthy only of ridicule that bestows a tear with greater promptitude than a shilling. For the irony of Swift, Sterne substituted buffoonery, which, in conformity with the opinion of Aristotle, the dean regarded as the less liberal species of pleasantry. But the strongest objection to much of the satire in Tristram Shandy is, that the author threw away his ridicule upon pedantry that had become altogether obsolete.

It would be harsh justice to conclude, that the beauties of Sterne's writings are drawn from some yet undiscovered source, because he is known to have had confused notions on the subject of literary honesty, and to tear the laurel from his brows, because some of its leaves are purloined from the tombs of the dead. "Every man's wit," he says, "must come from every man's own soul, and no other body's." That he had much wit of his own, there is reason as well as charity in supposing, although his propensity to make free with the wit of others may justify some suspicion on the subject, upon the principle that a rich man, who retains the use of his reason, is seldom guilty of theft. And it cannot be denied, that the world would be indebted to the writer who could produce such another tissue of reproductions, if such it is, as "The Life and Opinions of Tristram Shandy, Gent."

STERNOMANTIS, in *Antiquity*, a designation given to the Delphian priestess, more usually called PYTHIA. Sternomantis is also used for any one that had a prophesying demon within him.

STERNUTATIVE, or STERNUTATORY, a medicine proper to produce sneezing.

STETTIN, one of the governments into which the Prussian province of Pomerania is divided. It extends over 4895 square miles, comprises forty cities and market-towns, and 1510 villages. It is divided into eleven circles. The

inhabitants amounted in 1817 to 327,002, and in 1831 to 432,570; the whole of them adhering to the Lutheran church, with the exception of about 3000 Catholics and 1500 Jews. It has been formed out of the whole of the former province of Pomerania and the western part of Hither Pomerania. The capital is the city of the same name, situated on the left bank of the river Oder, from which it has a gradual ascent. It is a well-built city, but some of its streets are steep. It is strongly fortified, has a citadel, and a fine place of arms, and storehouses for munitions of war. From its position near the mouth of such a river, it has facilities for carrying on a very extensive commerce. The productions of foreign countries are conveyed from it to the cities of Kustrin, Frankfurt, Breslau, and even to Cracow; and it is the best shipping port for the productions of the districts which surround those cities. The larger classes of vessels cannot ascend to Stettin, but are loaded or discharged by means of barges at the port of Swinemunde, near the discharge of the Fresh Haff into the Baltic. It contains a fine old royal palace, a Gothic cathedral with two lofty towers, a gymnasium, to which belong an astronomical observatory, a library, and museums. It has considerable manufactories of linen and woollen goods, tobacco and snuff, several sugar refineries, tanneries, soap-boilers' works, and extensive breweries and distilleries. Many vessels are built at Stettin, and more than 200 are owned by the merchants of the city. About 800 ships yearly enter and clear out. The city, with the suburbs, contains 32,191 inhabitants, and the markets are well and cheaply supplied. Long. 14. 50. 25. E. Lat. 52. 25. 36. N.

STEVENAGE, a town of the hundred of Broadwater, in the county of Hertford, thirty-one miles from London. It formerly belonged to the abbot of Westminster. The church, which stands on a hill, is an ancient building, with a large square tower. There is a free grammar-school, and an endowed alms-house. This town has a market on Wednesday. The inhabitants amounted in 1801 to 1254, in 1811 to 1302, in 1821 to 1664, and in 1831 to 1859.

STEWARD (*senescallus*, compounded of the Saxon *steda*, i. e. "room" or "stead," and *weard*, "a ward" or "keeper"), an officer appointed in another's stead or place, and always taken for a principal officer within his jurisdiction. Of these there are various kinds. The greatest officer under the crown is the lord high steward of England, whose office was anciently the inheritance of the earls of Leicester, till forfeited by Simon de Montfort to King Henry III. But the power of this officer is so very great, that it has not been judged safe to trust it any longer in the hands of a subject, excepting only for a particular occasion; as to officiate at a coronation, or at the arraignment of a nobleman for high treason or felony. During his office, the steward bears a white staff in his hand; and when the trial is ended, he breaks the staff, and with it his commission expires. There is likewise a lord steward of the king's household, who is the chief officer of the king's court, has the care of the king's house, and authority over all the officers and servants of the household, except such as belong to the chapel, chamber, and stable.

The court of the lord high steward of Great Britain, is a court instituted for the trial of peers indicted for treason or felony, or for misprision of either. When such an indictment is found by a grand jury of freeholders in the king's bench, or at the assizes before the justices of *oyer and terminer*, it is to be removed by a writ of *certiorari* into the court of the lord high steward, which has the only power to determine it. A peer may plead a pardon before the court of king's bench, and the judges have power to allow it, in order to prevent the trouble of appointing a high steward merely for the purpose of receiving such plea; but he may not plead in that inferior court any other plea, as guilty or not guilty of the indictment, but only in this court;

Stevenage
||
Steward.

Stewart, because, in consequence of such plea, it is possible that judgment of death might be awarded against him. The king, therefore, in case a peer be indicted of treason, felony, or misprision, creates a lord high steward *pro hac vice* by commission under the great seal; which recites the indictment so found, and gives his Grace power to receive and try it *secundum legem et consuetudinem Angliæ*. During the session of parliament the trial of an indicted peer is not properly in the court of the lord high steward, but before the court of our lord the king in parliament. It is true, a lord high steward is always appointed in that case, to regulate and add weight to the proceedings; but he is rather in the nature of a speaker *pro tempore*, or chairman of the court, than the judge of it; for here the collective body of the peers are the judges both of law and fact, and the high steward has a vote with the rest in right of his peerage. But in the court of the lord high steward, which is held in the recess of parliament, he is the sole judge of matters of law, as the lords triors are in matters of fact; and as they may not interfere with him in regulating the proceedings of the court, so he has no right to intermix with them in giving any vote upon the trial. In the conviction and attainder of a peer for murder in full parliament, it has therefore been held by the judges, that in case the day appointed in the judgment for execution should lapse before execution done, a new time of execution may be appointed by either the high court of parliament during its sitting, though no high steward be existing, or, in the recess of parliament, by the court of king's bench, the record being removed into that court.

STEWART, MATTHEW, D.D., an eminent mathematician, was in 1717 born at Rothsay in the Isle of Bute, of which parish his father was minister. Being intended for the church, he passed through the usual course of a grammar-school education, and was in 1734 received as a student into the university of Glasgow. There he had the happiness of having for his preceptors in moral science and mathematics the celebrated professors Hutcheson and Simson, by the latter of whom he was instructed in what may not improperly be called the *arcana* of the ancient geometry.

His views making it necessary for him to remove to Edinburgh, he was introduced by Dr Simson to Mr Maclaurin, that his mathematical studies might suffer no interruption; and he attended the lectures of that great master with such advantage as might be expected from eminent abilities, directed by the judgment of him who made the philosophy and geometry of Newton intelligible to ordinary capacities. From his intimacy with Simson he had however acquired such a predilection for the ancient geometry, as the modern analysis, however powerfully recommended, could not lessen; and he kept up a regular correspondence with his old master, giving him an account of his progress and his discoveries in geometry, and receiving in return many curious communications respecting the *Loci Plani*, and the porisms of Euclid.

While the second invention of porisms, to which more genius was perhaps required than to the first discovery of them, employed Dr Simson, his pupil pursued the same subject in a different and new direction. In doing so, he was led to the discovery of those curious and interesting propositions which were published under the title of *General Theorems* in 1746. They were given without the demonstrations, but did not fail to place their discoverer at once among the geometers of the first rank. They are for the most part porisms, though Mr Stewart, careful not to anticipate the discoveries of his friend, gave them no other name than that of theorems.

Before this period he had entered the church, and through the patronage of the Duke of Argyll and the Earl of Bute he obtained the living of Roseneath, a retired country parish in the west of Scotland; but in 1747 he was elected to

the mathematical chair in the University of Edinburgh, which had become vacant the year before by the death of Mr Maclaurin. The duties of this office gave a turn somewhat different to his pursuits, and led him to think of the most simple and elegant means of explaining those difficult propositions which were hitherto only accessible to men deeply versed in the modern analysis. In doing this, he was pursuing the object which of all others he most ardently wished to attain, namely, the application of geometry to such problems as the algebraic calculus alone had been thought able to resolve. His solution of Kepler's problem was the first specimen of this kind which he gave to the world; and it was impossible to have produced one more to the credit of the method which he followed, or of the abilities with which he applied it. On this problem the utmost resources of the integral calculus had been employed. But though many excellent solutions had been given, there was none of them at once direct in its method and simple in its principles. Mr Stewart was so happy as to attain both these objects; and his solution appeared in the second volume of the *Essays of the Philosophical Society of Edinburgh* for the year 1756. In the first volume of the same collection there are some other propositions of Mr Stewart's, which are an extension of a curious theorem in the fourth book of Pappus. They have a relation to the subject of porisms, and one of them forms the ninety-first of Dr Simson's *Restoration*. They are besides very beautiful propositions, and are demonstrated with all the elegance and simplicity of the ancient analysis.

The prosecution of the plan which he had formed of introducing into the higher parts of mixed mathematics the strict and simple form of ancient demonstration, produced the *Tracts Physical and Mathematical*, which were published in 1761, and the *Essay on the Sun's Distance*, which was published in 1763. In this last work it is acknowledged that he employed geometry on a task which geometry cannot perform; but while it is granted that this determination of the sun's distance is by no means free from error, we may venture to affirm that it contains a great deal which will always interest geometers, and will always be admired by them. Few errors in science are redeemed by the display of so much ingenuity, and, what is more singular, of so much sound reasoning. The investigation is everywhere elegant, and will probably be long regarded as a specimen of the most arduous inquiry which has been attempted by mere geometry.

The *Sun's Distance* was the last work which Dr Stewart published; and though he lived to see several animadversions on it made public, he declined entering into any controversy. His disposition was far from polemical; and he knew the value of that quiet which a literary man should rarely suffer his antagonists to interrupt. He used to say, that the decision of the point in question was now before the public; that if his investigation was right it would never be overturned, and that if it was wrong it ought not to be defended. A few months before he published the essay just mentioned, he gave to the world another work, entitled *Propositiones Geometricæ more Veterum demonstratæ*. This title, it is said, was given to it by Dr Simson, who rejoiced in the publication of a work so well calculated to promote the study of the ancient geometry. It consists of a series of geometrical theorems, for the most part new; investigated first by an analysis, and afterwards synthetically demonstrated by the inversion of the same analysis. Dr Stewart's constant use of the geometrical analysis had put him in possession of many valuable propositions which did not enter into the plan of any of the works that have been enumerated. Of these not a few have found a place in the writings of Dr Simson, where they will for ever remain to mark the friendship of these two mathematicians, and to evince the esteem which Simson entertained for the abilities of his pupil.

Soon after the publication of the *Sun's Distance*, Dr

Stewart,
Dugald.

Stewart's health began to decline, and the duties of his office became burdensome to him. In the year 1772 he retired to a small demesne which he possessed in Ayrshire, where he afterwards spent the greater part of his life, and never resumed his labours in the university. But though mathematics had now ceased to be his business, they continued to be his amusement till a very few years before his death, which happened on the 23d of January 1785, at the age of sixty-eight.

The habits of study, in a man of original genius, are objects of curiosity, and deserve to be remembered. Concerning those of Dr Stewart, his writings have made it necessary to remark, that from his youth he had been accustomed to the most intense and continued application. In consequence of this application, added to the natural vigour of his mind, he retained the memory of his discoveries in a manner that will hardly be believed. He rarely wrote down any of his investigations till it became necessary to do so for the purpose of publication. When he discovered any proposition, he would put down the enunciation with great accuracy, and on the same piece of paper would construct very neatly the figure to which it referred. To these he trusted for recalling to his mind at any future period the demonstration or the analysis, however complicated it might be. Experience had taught him that he might place this confidence in himself without any danger of disappointment; and for this singular power he was probably more indebted to the activity of his invention than the mere tenaciousness of his memory. Though he was extremely studious, he read few books, and verified the observations of M. d'Alembert, that of all men of letters, mathematicians read least of the writings of one another. His own investigations occupied him sufficiently; and indeed the world would have had reason to regret the misapplication of his talents, had he employed in the mere acquisition of knowledge that time which he could dedicate to works of invention.

STEWART, *Dugald*, the illustrious son of the eminent mathematician whose merits are recorded in the preceding article, was born at Edinburgh on the 22d of November 1753. As a pupil in the High School of his native city, he was remarkable for the command of language exhibited in his exercises; and at college his turn for mental science began unequivocally to develop itself. In his nineteenth year he attended at Glasgow a course of lectures delivered by Dr Reid, of whose doctrines he was destined to be the most distinguished amender and expounder. In the course of that winter he composed, and read in a literary association, an essay on Dreaming, which afterwards took its place as an interesting section in his principal work.

But his youthful talents and acquirements were speedily subjected to a much more decisive test. Soon after the period of his studies in Glasgow, he assumed, on the decline of his father's health, the sole charge of his classes in the university of Edinburgh, and on the completion of his twenty-first year was appointed to the mathematical professorship, as assistant and successor. His popularity as a teacher in this department was remarkable; but when he was just twenty-five years old, an opportunity was fortunately afforded him of proving his qualifications for communicating knowledge in his favourite branch of philosophy. Dr Ferguson, the professor of moral philosophy, having gone to America on a public mission, Mr Stewart undertook to fill his place during the session of 1778-9: he entered on the duties of the situation within a week after having promised to discharge them; and for six months, besides teaching his two mathematical classes and a new class of astronomy, he delivered a course of lectures on ethics, thinking over every morning the subject of lecture for the day, and addressed his pupils without having written the discourse or made any further preparation. Those who then heard him considered

Stewart,
Dugald.

his extemporaneous lectures as possessing an energy and liveliness even exceeding that which distinguished his later addresses. He was soon transferred permanently to the post which he thus had temporarily filled; Dr Ferguson retiring in 1785, and Mr Stewart, then thirty-two years old, being appointed to the chair of moral philosophy in his room. While his fame as a lecturer rapidly spread all over Great Britain, he long abstained from communicating his speculations to the world in any more durable form. His earliest published work, the first volume of his *Elements of the Philosophy of the Human Mind*, did not appear till 1792. In 1793 he published his *Outlines of Moral Philosophy*, an unpretending text-book, but which exhibits his powers of generalization in the most favourable point of view. During several subsequent years his only publications were, the life of Dr Smith in 1793, that of Dr Robertson in 1796, and that of Dr Reid in 1802. These lives appeared in the *Transactions of the Royal Society of Edinburgh*. But, in the mean time, among his pupils he numbered many of those young men whose talents have since illustrated the northern division of the island; and, without naming those who have shone in political or professional life, it is enough to say that his *Elements* and his *Lectures* were the spark that first kindled the metaphysical genius of his own successor. As early likewise as 1780, before his first marriage, he had begun to receive into his family a few private pupils of rank; and some years after his second marriage in 1790, he again opened his house for the same purpose, and superintended the education of several who have occupied a prominent place as British statesmen. His ready command over his own mind was shown, not only by the ease with which he discharged the duties involved in these various avocations, but by his adding to his former course of instruction, in 1800, a series of lectures on Political Economy, which however were not continued. Nor is it unimportant to add, that on several occasions when his colleagues were incapacitated from acting, he temporarily gave lectures on natural philosophy, logic, and rhetoric.

In the winter of 1808-9, Mr Stewart, still in the zenith of his fame, but suffering under ill health, and dejected by the recent loss of his younger son, found himself obliged for a time to discharge the duties of his chair by deputy. In the following session his indisposition was more prolonged; and, strongly attached to private study, and sensitively alive to his reputation as a public teacher, he resolved to retire altogether from active life. In May 1810, Dr Thomas Brown, his late assistant, was in consequence conjoined with him as the acting professor.

After his retirement he lived constantly, as he had formerly done occasionally, at Kinneil House, situated on the Firth of Forth, about twenty miles west from Edinburgh. In this retreat he finished his volume of *Philosophical Essays*, which was published in 1810, and attained very extensive popularity. The second volume of his *Elements of the Philosophy of the Human Mind* appeared in 1813; and in the end of 1815 that *Dissertation on the Progress of Metaphysical and Ethical Philosophy*, which, originally written for the Supplement to this *Encyclopædia*, has now its place as the opening treatise of the present edition. He published nothing further between that time and the year 1822, when he suffered a severe stroke of palsy. But his mind was unshaken and untouched; and his compositions after this time were as vigorous in every respect as those which had preceded. The third volume of the *Elements* was published in 1827; and in 1828, a few weeks only before his death, his view of the Active and Moral Powers of Man was given to the world, in two volumes octavo. On the 11th of June 1828, he died at Edinburgh, in the seventy-fifth year of his age, and was buried in the Canongate churchyard. A monument to his memory, erected by his friends and admirers, and successfully imitated from one of the most

Stewart's
Islands
||
Steyer-
mark.

beautiful structures of Athens, forms a prominent object on the Calton Hill.¹ (B. L.)

STEWART'S *Islands*, a cluster of small, low islands, in the South Pacific Ocean, discovered by Captain Hunter in 1791. They are five in number. Long. 163. 18. E. Lat. 8. 26. S.

STEYER, a city of Austria, in the province of the Upper Ens, the capital of the circle of Traun. It stands at the junction of the two rivers Steyer and Traun, which, when united, flow into the Danube. It is a place of great industry, and contains various manufactories. There are some of cotton and of linen goods; but the chief occupation is that of preparing cutlery and arms of various kinds, the latter chiefly for the imperial armies. The other necessities for the equipment of armies are also extensively fabricated. The city contains 10,640 inhabitants, having of late years greatly increased. Long. 14. 14. 45. E. Lat. 48. 4. 45. N.

STEYERMARK, or STEIERMARK, one of the provinces of the Austrian empire. Its name is derived from an ancient palace at the junction of the Steyer with the Ens, which in the twelfth century was inhabited by a Count Trugau, who was ruler over a part of Carinthia, then an independent duchy. It extends in north latitude from 45° 54' to 47° 50', and in east longitude from 13° 26' to 16° 19', being an extent of 8600 square miles. It comprehends twenty cities, ninety-six market-towns, and 3540 villages, with a population, according to the last census, of 869,000 persons, all adhering to the Catholic church, with the exception of four Lutheran congregations and a few Jews. It is bounded on the north by the province of Lower Ens, on the east by Hungary, on the south by the Illyrian province of Laybach, and on the west by that province and the Upper Ens. The northern and western divisions of the province are covered with the lofty mountains of the Julian Alps, divided into two branches. These mountains in no case reach the line of perpetual snow, the highest of them, called the Grossenberg, being but 8380 feet, and the others from 3250 to 7600 feet. The southern and eastern parts of the province are less elevated, consisting of plains and undulating hills. The mountains give rise to numerous rivulets, which form within it large rivers, all of which terminate in the Danube. The principal of these are the Mur, the Drave, the Ens, and the Raab. There are no extensive lakes, but many of small extent, and some of them in very elevated situations. It abounds in mineral springs, both warm and cold, and containing various combinations of iron, salt, and sulphur; but they are not much repaired to by invalids. One half of the province is covered with woods, which yield fuel and timber for building, and contain abundance of game both of the larger and smaller kind. Of the former kind are roebucks, wild swine, gemsen, and bears, as well as beasts of prey, especially wolves and lynxes. The land in the valleys is fertile and well cultivated, and produces good corn, a great proportion of which is maize, forming the chief food of the labouring classes. More than 60,000 acres are cultivated with vines, which produce tolerable wine. Hemp and flax are sufficiently raised to provide clothing, with the aid of the wool of about 150,000 sheep. The mineral productions are various. Salt is the most considerable in quantity. Iron is produced, and is converted into utensils for internal use, but not for exportation. Silver is raised to the extent of about 60,000 ounces yearly, and likewise some copper, cobalt, alum, vitriol, and sulphur. The commerce is not extensive, except between the upper and lower parts of the province, though some is carried on both with other parts of Germany and with Austrian Italy. One of the great roads

to Lombardy passes through this province. It still retains some privileges respecting the assembling of the states, but they are of little practical efficacy. The capital is Gratz, a city of 40,000 inhabitants.

STEYNING, a town of the hundred of that name, in the rape of Bramber and county of Sussex, fifty-one miles from London. It is ill built, but has a curious church, of Norman architecture, and was the burial-place of some of the Saxon kings. It returned two members to the House of Commons, but was disfranchised by the act of 1832. It has a market on Wednesday, and several fairs at which great numbers of sheep are sold. The inhabitants amounted in 1801 to 1174, in 1811 to 1210, in 1821 to 1324, and in 1831 to 1436.

STIBADIUM, among the Romans, a low kind of table, couch, or bed, of a circular form, which succeeded to the triclinia, and was of different sizes according to the number of guests for which it was designed. Tables of this kind were called *hexaclina*, *octaclina*, or *enneaclina*, according as they held six, eight, or nine guests, and so of any other number.

STICCATO (*Ital.*), a rude musical instrument, formed of a number of sticks of hard wood of different lengths, generally attached to each other by strings at the ends, but so as to hang separate from one another when suspended by the top. It is played upon by striking the sticks with rods of cane or whalebone tipped with ivory balls. Mersenne, in his *Harmonia Universalis*, calls this instrument *lignum psalterium*.

STICHOS, a name given by the old writers to a pectoral confection, the principal ingredient of which was the herb *marrubium* or horehound.

STIGMATA, in *Natural History*, the apertures in different parts of the bodies of insects, communicating with the tracheæ or air-vessels, and serving for the office of respiration.

STIGMATA, in *Antiquity*, certain marks impressed on the left shoulder of the soldiers when listed.

STIGMATA were also a kind of notes or abbreviations, consisting only of points disposed various ways; as in triangles, squares, crosses, &c.

STIGMATA is likewise a term used among the Franciscans, to express the marks or prints of our Saviour's wounds, said to have been miraculously impressed by him on the body of their seraphic father St Francis.

STIGMATIZING, among the ancients, was inflicted upon slaves as a punishment, but more frequently as a mark to distinguish them: in which case it was done by applying a red-hot iron marked with certain letters to their foreheads, till a fair impression was made; and then pouring ink into their furrows, that the inscription might be the more conspicuous. It was customary to stigmatize the worshippers and votaries of some of the gods. The marks used on these occasions were various; sometimes they contained the name of the god, sometimes his particular ensign, as the thunderbolt of Jupiter, the trident of Neptune, the ivy of Bacchus; or they marked themselves with some mystical number, by which the god's name was described. To these three ways of stigmatizing St John is supposed to refer (Rev. chap. xiii. ver. 16, 17). Theodoret is of opinion that the Jews were forbidden to brand themselves with stigmata, because the idolaters, by that ceremony, used to consecrate themselves to their false gods. Among some nations, stigmatizing was considered as a distinguishing mark of honour and nobility. In Thrace, as Herodotus informs us, it was practised by none but persons of credit, nor omitted by any but persons of the meanest rank. The ancient Britons are also said to have

Steyning
||
Stigmatiz-
ing.

¹ The Editor had hoped to have the gratification of introducing into this work, so deeply indebted to this great and good man, a more detailed account of his life and writings; but circumstances induced him to abandon the design, and to give a place only to the above brief notice, contributed by one of his literary assistants.

Stilling-
fleet.

imprinted on the bodies of their infants the figures of animals, and other marks, with hot irons.

STILLINGFLEET, EDWARD, bishop of Worcester, was the son of Samuel Stillingfleet, gentleman, and was born at Cranborn in Dorsetshire in 1635. He was educated at St John's College, Cambridge; and having received holy orders, was, in 1657, presented to the rectory of Sutton in Nottinghamshire. By publishing his *Origines Sacrae*, one of the ablest defences of revealed religion that has ever been written, he soon acquired such reputation, that he was appointed preacher of the Rolls Chapel; and in January 1665 was presented to the rectory of St Andrews, Holborn. He was afterwards chosen lecturer at the Temple, and appointed chaplain in ordinary to King Charles II. In 1668 he took the degree of D.D.; and was soon after engaged in a dispute with those of the Romish religion, by publishing his discourse concerning the idolatry and fanaticism of the church of Rome, which discourse he afterwards defended against several antagonists. In 1680 he preached at Guildhall chapel a sermon on Phil. iii. 26, which he published under the title of "The Mischief of Separation;" and this being immediately attacked by several writers, he in 1683 published his Unreasonableness of Separation. In 1685 appeared his *Origines Britannicae*, or the Antiquities of the British Churches, in folio. During the reign of King James II. he wrote several tracts against popery, and was prolocutor of the convocation, as he had likewise been under Charles II. After the revolution he was advanced to the bishopric of Worcester, and was engaged in a dispute with the Socinians, and also with Mr Locke; in which last contest he is generally thought to have been unsuccessful. He died at Westminster in 1699, and was interred in the cathedral of Worcester, where a monument was erected to his memory by his son. Dr Stillingfleet wrote other works besides those here mentioned, which, with the above, have been reprinted in 6 vols. folio.

STILLINGFLEET, Benjamin, an ingenious naturalist, born in 1702, was the bishop's grandson. His father, Edward Stillingfleet, M.D., was fellow of St John's College, Cambridge, and Gresham professor of physic: but marrying in 1692, he lost his lucrative offices and his father's favour; a misfortune that affected both himself and his posterity. Having however entered the church, he obtained, by his father's means, the living of Newington-Butts, which he immediately exchanged for those of Wood-Norton and Swanton in Norfolk. He died in 1708. Benjamin, his only son, was educated at Norwich school, which he left in 1720, with the character of an excellent scholar. He then went to Trinity College in Cambridge, at the request of Dr Bentley, the master, who had been private tutor to his father, domestic chaplain to his grandfather, and much indebted to the family. Here he was a candidate for a fellowship, but was rejected by the master's influence. This was a severe and unexpected disappointment, and but little alleviated afterwards by Bentley's apology, that it was a pity that a gentleman of Mr Stillingfleet's parts should be buried within the walls of a college.

Perhaps, however, this ingratitude of Dr Bentley was not of any real disservice to Mr Stillingfleet. By being thrown into the world, he formed many honourable and valuable connections. He dedicated some translations of Linnæus to the late Lord Lyttelton, partly; he says, from motives of private respect and honour. Lord Barrington gave him, in a very polite manner, the place of master of the barracks at Kensington; a favour to which Mr Stillingfleet, in the dedication of his Calendar of Flora to that nobleman, alludes with the greatest politeness, as well as the warmest gratitude. His Calendar of Flora was formed at Stratton in Norfolk in the year 1755, at the hospitable seat of his very worthy and ingenious friend Mr Marsham, who had made several observations of that kind, and had communi-

cated to the public his curious observations on the growth of trees. But it was to Mr Wyndham of Felbrig in Norfolk that he appears to have had the greatest obligation: he travelled abroad with him, spent much of his time at his house, and was appointed one of his executors (Mr Garrick being another), with a considerable addition to an annuity which that gentleman had settled upon him in his lifetime.

Mr Stillingfleet's genius seems, if we may judge from his works, to have led him principally to the study of natural history; which he prosecuted as an ingenious philosopher, an useful citizen, and a good man. In this walk of learning he mentions as his friends, Dr Watson, Dr Solander, Mr Hudson, Mr Price of Foxley, and some others; to whom may be added the ingenious Mr Pennant. Nor can we omit the flattering mention which Mr Gray makes of him in one of his letters, dated from London in 1761: "I have lately made an acquaintance with this philosopher, who lives in a garret here in the winter, that he may support some near relations who depend upon him. He is always employed, consequently (according to my old maxim) always happy, always cheerful, and seems to me a very worthy, honest man. His present scheme is to send some persons, properly qualified, to reside a year or two in Attica, to make themselves acquainted with the climate, productions, and natural history of the country, that we may understand Aristotle, Theophrastus, &c. who have been heathen Greek to us for so many ages; and this he has got proposed to Lord Bute, no unlikely person to put it in execution, as he is himself a botanist."

Mr Stillingfleet published a volume of Miscellaneous Tracts, which is in much esteem, and does great honour to his head and heart. They are chiefly translations of some essays in the *Amœnitates Academicæ*, published by Linnæus, interspersed with some observations and additions of his own. In this volume he shows also a taste for classical learning, and entertains us with some elegant poetical effusions of his own. But his Essay on Conversation, published in the first volume of Dodsley's Collection of Poems, entitles him to a respectable station among our English poets. This poem is addressed to Mr Wyndham, with all that warmth of friendship which distinguishes Mr Stillingfleet. As it is chiefly didactic, it does not admit of so many ornaments as some compositions of other kinds. However, it contains much good sense, shows a considerable knowledge of mankind, and has several passages that, in point of harmony and easy versification, would not disgrace the writings of our most admired poets. Here more than once Mr Stillingfleet shows himself still sore for Dr Bentley's cruel treatment of him; and towards the beautiful and moral close of it, where it is supposed he gives us a sketch of himself, seems to hint at a mortification of a more delicate nature, which he is said to have suffered from the other sex. To these disappointments it was perhaps owing that Mr Stillingfleet neither married nor went into orders. His London residence was in lodgings in Piccadilly, where he died in 1771, at the age of sixty-nine, leaving several valuable papers behind him. He was buried in St James's church, without the slightest monument to his memory.

STILPO, a celebrated philosopher of Megara, flourished under the reign of Ptolemy Euergetes. In his youth he had been addicted to licentious pleasures, from which he religiously refrained from the moment when he ranked himself among philosophers. When Ptolemy Soter, at the taking of Megara, offered him a large sum of money, and requested that he would accompany him into Egypt, he accepted but a small part of the offer, and retired to the island of Ægina, whence, on Ptolemy's departure, he returned to Megara. That city being again taken by Demetrius the son of Antigonus, and the philosopher required to give an account of any effects which he had lost during the hurry of the plunder, he replied that he had lost nothing;

Stilpo.

Stilobatum
||
Stirling.

for no one could take from him his learning and eloquence. So great was the fame of Stilpo, that the most eminent philosophers of Athens took pleasure in attending upon his discourses. His peculiar doctrines were, that species or universals have no real existence, and that one thing cannot be predicated of another. With respect to the former of these opinions, he seems to have taught the same doctrine with the sect afterwards known by the appellation of *Nominalists*. To prove that one thing cannot be predicated of another, he said, that *goodness* and *man*, for instance, are different things, which cannot be confounded by asserting the one to be the other. He argued further, that goodness is a universal, and universals have no real existence; consequently, since nothing cannot be predicated of any thing, goodness cannot be predicated of man. Thus, while the subtile logician was, through his whole argument, predicating one thing of another, he denied that any one thing could be the accident or predicate of another. If Stilpo was serious in this reasoning, if he meant any thing more than to expose the sophistry of the schools, he must be confessed to have been an eminent master of the art of wrangling; and it was not wholly without reason that Glyceria, a celebrated courtesan, when she was reproved by him as a corrupter of youth, replied, that the charge might be justly retorted upon himself, who spent his time in filling their heads with sophistical quibbles and useless subtleties. In ethics he seems to have been a Stoic, and in religion he had a public and a private doctrine, the former for the multitude, and the latter for his friends. He admitted the existence of a Supreme Divinity, but had no reverence for the Grecian superstitions.

STILOBATUM, in *Architecture*, denotes the body of the pedestal of any column.

STILTON, a town of the hundred of Normancross, in the county of Huntingdon, seventy-four miles from London. It stands on the great north road, and has many good inns, with post-horses. It has long been celebrated for the excellence of its cheese. The inhabitants amounted in 1801 to 509, in 1811 to 663, in 1821 to 710, and in 1831 to 793.

STIMULANTS, in *Medicine*, substances which increase the action of certain parts of the body. In particular, they quicken the motion of the blood, increase the action of the muscular fibres, and affect the nervous system.

STING, an apparatus in the bodies of certain insects, in the form of a little spear, serving them as a weapon of offence.

STIPULATION, in the civil law, the act of stipulating, that is, of treating and concluding terms and conditions to be inserted in a contract. Stipulations were anciently performed at Rome, with abundance of ceremonies; the first of which was, that one party should interrogate, and the other answer, to give his consent, and oblige himself. By the ancient Roman law, nobody could stipulate but for himself; but as the tabelliones were public servants, they were allowed to stipulate for their masters; and the notaries succeeding the tabelliones, have inherited the same privilege.

STIRLING, one of the most ancient towns in Scotland, and capital of the county of the same name, is situated in 5° 45' west longitude, and 56° 6' north latitude, in a plain called the Carse, watered by the river Forth, and on the sloping ridge of a rock, at the western and precipitous extremity of which the castle is built. The town is very irregular, the street upon the crest of the hill being broad and spacious, but the other streets narrow and inconvenient. Within the last few years great improvements have been undertaken. The pavement of the streets, which was of the worst description, has been rendered equal to that

of almost any other place in the kingdom; and the opening of the town at its lower extremity is affording scope for the most marked improvements. Many elegant houses and fine shops have been erected. In the suburbs there are many handsome villas; in Southfield, Melville Terrace, Allan Park, Wellington Place, and Dunbarton Road. Stirling is a most convenient place for the residence of people of small but easy fortune. House-rents are low; and ground for gardens may be procured upon easy terms. There are no local public burdens of any kind; the streets being lighted and cleaned, and water brought to the town, at the expense of the corporation. The situation of Stirling is very convenient in other respects. The steam-boats supply an easy and cheap conveyance to and from Edinburgh; and many coaches pass through the town in different directions. "In point of extent, variety, and magnificence, the view from Stirling Castle is perhaps unequalled by any other in Britain."¹

The public buildings are the two parish churches, both in the Gothic style, with a modern erection between them, which adds nothing to their beauty: they are called the East and West Churches. The former is a fine building, erected in the year 1494. In the two churches there are three clergymen, and in one of the United Secession churches two. The town council has the patronage of the churches, and two of the ministers are entirely supported by the corporation. It also bears the whole expenses of the jail for the counties of Stirling, Clackmannan, and Kinross, except a part of the jailer's salary, paid by the counties. Besides two chapels belonging to the United Associate Synod, there is an Old Light church, the minister of which, and a majority of the congregation, have within a few weeks joined the established church. There are likewise an Episcopal and a Roman Catholic chapel, the latter a neat building, erected within the last two years; a Cameronian, a Congregational, and several Baptist places of worship. The town-house, with a spire, in which there is a set of music-bells, which play a tune before the striking of each hour, and the jail behind, which is very insecure, form two sides of a quadrangle, the third side of which is finely fitted up as a court-room, in which the circuit court sits twice a year, and also frequently the sheriff court. The fourth side of the quadrangle is private property, which is very inconvenient. In the town-house are still kept the pint jug, the ancient legal standard for liquid measure in Scotland, and two silver keys, representative of the keys of the two ancient gates of the town; and in the circuit court-room about a dozen of the fine ancient carvings known by the name of the Stirling heads. In the narrow lane leading to the castle, there is a military hospital. The building was once the property of the Argyle family, and is still called Argyle House. Near it, and close beside the two churches, is situated a ruin, called Mar's Work. It is an unfinished house, begun, but never completed, by the regent Mar. The Athenæum is a handsome house in King Street, with a spire 120 feet high. In the ground-floor there are shops, but the two upper stories contain, the first a public reading-room, to which respectable strangers have access at all times, and the second a subscription library, containing about 5000 volumes. Close beside the Athenæum is the corn-market, for the accommodation of which a splendid hall has been erected within the last twelvemonths. There are three public school-houses in the town. The parish school has four departments, viz. a grammar-school, a mathematical, and two English schools. In addition to their fees, the teachers have each a salary of fifty pounds from the town council; and the master of the grammar-school has twenty pounds more for an assistant. Education is cheap and good. In the town there are four charitable endowments, commonly called hospitals, in full

Stirling.

¹ M'Culloch's Statistical Account of the British Empire, vol. i. p. 299.

Stirling.

operation, two for the support of the aged poor, and two for educating the young. One of the former has an income approaching to L.3000 annually, wholly arising from land; but when public burdens are paid, with necessary repairs, there remains scarcely one half for the support of the poor, who receive from 8s. to 1s. 6d. per week, according to circumstances. Two of the others have incomes of about L.700 each, derived in the same way, and bearing the same burdens. The fourth has the interest of L.4000. The two latter educate, clothe, and allow 2s. 6d. a week to between forty and fifty boys. The funds of the whole of these are distributed to parties designated by the founders; all having their operation according to the old constitution of the borough. They are, like every thing else in the town, under the patronage and management of the town council, with the addition in one case of the first, and in another of the second, minister. In addition to these, the late Mr John Maclaren of Liverpool, a native of Stirling, has bequeathed a sum, the amount of which is not yet fully known, for the purpose of founding and endowing schools upon a most liberal scale, for the instruction, not wholly gratuitous, but at a very low rate, of children from four to sixteen years of age. A clause in his will provides that no clergyman shall have any control or management of his fund. One of the above charities had an hospital built for the accommodation of twelve decayed members of the incorporation of guildry, but nobody could be persuaded to inhabit it, although pleasantly situated. The consequence was, that the funds accumulated, until what was originally L.2222 sterling, has now increased to about L.3000 yearly. As in these circumstances the intentions of John Cowane, the founder, could not be carried into effect, the town council and the first minister, who are the governors, have for a long period been in the habit, and latterly with the consent of the Court of Session, of dividing the funds among the poor belonging to the incorporation, so that now upwards of 180 persons are deriving benefit to the amount of from 8s. to 1s. 6d. a week, from a fund which was intended for the support of only twelve. The hospital stands near the East and West Churches, ornamented with a small spire and a statue of Cowane; and its hall is now used for the meetings of the guildry. The other charity had also an hospital, which is still standing, without however being the property of the charity; and the funds are divided in a similar manner among the poor of the seven incorporated trades. They are all at present in a thriving condition. Besides the above charities, the general poor of the town are supported by the kirk-session, the various churches to which they belong, and by a voluntary subscription denominated the poor-scheme; the people preferring this mode to a regular assessment, of which they have a salutary dread. There is also a public dispensary, which affords relief to many. Notwithstanding all these provisions, public mendicancy is exceedingly common; nor do the authorities, from false notions of humanity, exert themselves to put a stop to this practice, so degrading to the poor, and annoying to the public.

The literature of the place is sustained by two reading-rooms, one of which belongs to artisans. The public library, already noticed, is under excellent management, excepting that the entry-money and annual payment are both too high; it has about 140 subscribers. The School of Arts, or Mechanics Institution, generally supports a course of lectures in the winter season, attended by from 200 to 300 males and females. It possesses also a chemical and electrical apparatus, and various other philosophical instruments, and something like the foundation of a museum. To the care of this institution, a gentleman in Manchester, a native of Stirling, has committed a number of fine casts, principally from the antique, which form a small but interesting gallery of statuary. It is daily open for the inspection of the public. This society has also an excellent li-

Stirling.

brary, consisting of upwards of 1000 volumes, which are very much read. The price of admittance to all the benefits of the institution is only four shillings a year. All that is wanting to render it a most useful institution, is a house to contain its literary wealth. In almost every one of the churches and chapels there is also a congregational library, chiefly consisting of theological, although some admit historical works. Besides those of a general nature, there is also a consulting library for the legal profession, a medical, and likewise a horticultural library. There is likewise a singular kind of library, of which Stirling is the centre. It circulates among the landed gentlemen chiefly in the neighbourhood, and the subscription is at least two guineas a year. The funds are expended upon publications of the current year, at the end of which they are sold, and the proceeds are added to the stated contributions. This town has two weekly newspapers, the Stirling Journal and the Stirling Observer, the former Tory, and the latter Whig, both having an average provincial circulation.

The chief article of domestic trade in Stirling, situated as it is in a large and fertile district, now under the best culture, is grain of all kinds, amounting, it is said, to the value of upwards of L.500,000 annually, there being a great deal of barley consumed in the distilleries and breweries, which are numerous and upon extensive scales around Stirling. The manufactures are chiefly tartans, carpets, plaid-shawls, trouser-stuffs, and wool-spinning, which is beginning to be conducted with spirit in the town. Stirling shalloons, which figured so long in the statistics of the town, have now wholly disappeared, and their place is supplied by the articles enumerated above. Coach-building seems also to thrive here, as one establishment employs nearly seventy people, that of Mr Kinross, who within the last twelvemonth has been honoured with the distinction of coach-maker to the queen for Scotland. There are other two establishments, one of which has been lately commenced. To facilitate commercial and manufacturing industry, there are four stationary banks, and one which does business only on one day in each week, namely, on Friday, the market-day. They are all branches of banking establishments in Edinburgh or Glasgow. The commerce of the town is very limited, consisting chiefly of timber, grain for the distilleries, and a few other articles of little importance. There is a line of packets between Stirling and Leith, and another conveyance for goods by steam twice a week. But until the river be deepened, little improvement can be expected in this respect, as vessels above seventy tons burden cannot reach the town even at spring tide. The town council of Stirling is rather an important body, having the management of considerable funds; for, besides the sum already mentioned belonging to the charities, the town's finances, arising from salmon-fisheries, customs, shore-dues, &c., amount to between L.3000 and L.4000; all of which revenue is expended for the benefit of the public, in paving the streets, building and repairing the public markets, and other purposes, as has been already mentioned.

The castle, at the western extremity of the eminence upon which the town is built, is of greater antiquity than the town, and still exhibits marks of royal magnificence. Here James II. was born; and here also with his own hand he stabbed William earl of Douglas. The hall built by James III., who resided much here, for the meeting of parliament, is now used as barracks. The chapel royal, built by James VI. (who was educated here under the tuition of the celebrated George Buchanan) for the baptism of his son Prince Henry, and which was at that time the scene of one of the most pompous ceremonies ever exhibited in Scotland, is now fitted up as a store-room and armoury. The palace of James V. is a large quadrangular building, ornamented externally with many grotesque figures, and enclosing a small court called the lion's den. The lower story is

Stirling-shire.

now converted into barracks, with a canteen or sutlery; and the upper flat into apartments for the officers. In one of the apartments, called the king's room, the roof was covered with rich carvings in oak, which have been engraved and described in a work published in 1817, under the appellation of *Lucunar Strevelinense*. The quaint appellation of James V. *the gudeman of Ballingeich*, was derived from a hollow place immediately on the outside of the castle. Besides the places already noticed, the castle contains a large space, also surrounded by the exterior wall, in which magazines are built, called the Nether Baillery. The defences are the French, the Seven-Gun, and Queen Anne's Batteries, with several pieces of ordnance here and there, amounting in all to twenty-six. On the south side of the castle is a piece of flat ground called the Valley, which was appropriated for tournaments. It is now used as a horse-market. There is an adjoining rock called the Ladies Hill, whence they viewed the sports below. From the castle not fewer than twelve battle-fields are seen. In 1831 the population of Stirling was 8556. (D. E.)

Situation and boundaries.

STIRLINGSHIRE, a county in Scotland, partly maritime, being situated at the upper extremity of the Firth of Forth, and lying between $52^{\circ} 30'$ and $56^{\circ} 17'$ north latitude, and between $3^{\circ} 35'$ and $4^{\circ} 40'$ west longitude, upon the isthmus between the Forth and Clyde. It is bounded on the north by the counties of Perth and Clackmannan, on the east by the Firth of Forth and Linlithgowshire, on the south chiefly by Dunbartonshire; but at both the east and west extremities it is bounded for a few miles by Lanarkshire, and on the south-west and west by Dunbarton. Its length, upon the average of three measurements, is forty-two and a half miles; and its breadth, upon the average of six measurements, thirteen and a half, although in one parallel it extends to eighteen miles; and it contains 502 square miles, or 321,280 acres, divided into twenty-two entire parishes, with portions of other four which partly belong to the adjoining counties. The river and Firth of Forth is, for the most part, the boundary on the north, though parts of two parishes are on the north side of that river; on the west it includes part of Lochlomond, and a narrow neck extends to the north-west, the east side of which touches Loch Katrine. Like many other of the Scottish counties, it is of a very irregular form; yet most of its outline is well defined. Besides the Forth on the north and north-east, the Avon marks its separation from Linlithgowshire on the east and north-east, the Kelvin flows along a great part of the southern boundary, and the Endrick, before entering Lochlomond, divides it for some extent from Dunbartonshire on the west.

Surface.

About two thirds of Stirlingshire consist of hills unfit for cultivation, but affording good pasturage for sheep, being chiefly covered with green herbage, though sometimes intermixed with heath. The principal chain of this description, called the Lennox Hills, but having other distinctive names, as Campsie Fells, Fintry Hills, runs across the county, from Dunbartonshire on the west, nearly to the town of Stirling on the north, but it seldom presents an elevation of more than 1500 feet. In other quarters, however, the elevation is greater; Benlomond, on the north-west, on the banks of Lochlomond, being 3191 feet high; and Bencleuch, in the parish of Alva, on the north side of the Forth, upwards of 2400 feet. On the north, and still more on the east of the Lennox Hills, the country is low; the summit-level of the Forth and Clyde Canal, which passes through the south-eastern side, being only about 162 feet above the sea; and much of the land along the Forth is a very rich plain, only a few feet higher than the water. Towards the western and southern extremities the surface is more varied, presenting tracts of heath, moss, and green pastures, intermixed with cultivated land; the latter confined, for the most part, to the banks of the streams.

VOL. XX.

Stirlingshire has every variety of soil common in Scotland; but that for which it is chiefly distinguished is the alluvial or *carse* land on the Forth, which is computed to extend to about 40,000 English acres within this county, and twice as much more in the adjoining counties of Perth, Clackmannan, and Linlithgow, or in all to about 187 square miles; certainly by far the richest tract in Scotland. It consists of the finest particles of earth, without stones; in point of friability approaching to the character of loam; in some places 30 feet deep, and seldom more than 25 feet above the level of the sea at high water; and contains beds of shells, moss, and clay marl. In one instance, at the depth of 19 feet, there have been found in a stratum of moss the roots of large trees, deers horns, and bones, while the superior strata were composed entirely of fine earth. In another instance, the skeleton of a whale, now in the museum of the university of Edinburgh, covered with four feet of soil, was found in a field, the surface of which is 18 feet above the present average level of the Forth, from which it was a mile distant.

Stirling-shire.

Soil.

Coal, limestone, ironstone, and sandstone, abound in this county. Coal has not been found to the north and west of the Lennox Hills, but prevails very generally along their southern base, from Baldernock on the west, to Denny, St Ninian's, Falkirk, Larbert, and Airth, on the east; and generally throughout all the eastern quarter, on both sides of the Forth and Clyde Canal. By means of the Union Canal carried from the city of Edinburgh to the Forth and Clyde Canal near Falkirk, these extensive coal-fields have been rendered of easy access to the metropolis, which already receives large supplies of coal from that quarter, at little more than two thirds of the price which the inhabitants formerly paid for this necessary article. Limestone abounds in the same quarters with the coal, and in many instances there is one stratum of it above and another below the coal, the former always of the best quality. Sandstone also frequently accompanies both, though it is found in other parts. At Kilsyth there is a quarry of white sandstone, which takes a fine polish, and has been often used in ornamental work. Ironstone is in great abundance throughout the coal district, and is wrought in several places to a considerable extent, chiefly for the use of the Carron Works. It is also found in the parish of Kilsyth, in balls from a quarter of an inch to a foot in diameter, which are richer in metal than the common stone. Copper has not been discovered in veins so rich as to encourage their working, though mines were formerly opened at one or two places. Veins of silver were discovered, about sixty years ago, in the parishes of Logie and Alva, on the northern extremity of the county, and for a few weeks the working was very successful, but was soon abandoned. Cobalt was found in the same quarter. There are indications of other minerals in different parts of the county. In connection with the minerals it may be noticed, that in the parish of Logie, near to the beautiful village of Bridge of Allan, the mineral springs of Airthrey were discovered some years ago, and recommended to public notice. They are now attracting a great many visitors, and Bridge of Allan is rapidly assuming the appearance of a handsome town.

Besides the Forth, the Avon, the Kelvin, and the Endrick, Rivers, which, though having their sources in Stirlingshire, soon cease to belong to it exclusively, flowing for the most part on its boundaries, this district is well supplied with other streams, which traverse its interior. The Forth, however, is by far the most important. It rises from a spring on the northern side and near the summit of Benlomond. After a course of eight or ten miles, under the name of the Water of *Duchray*, it passes into Perthshire, where it is called *Avendhu*, or Black River; and soon after, on returning to the borders of this county, it obtains the name of the Forth. A few miles above Stirling it receives the Teith, and after-

The Forth.

4 Z

Stirling-shire.

wards the Allan, from the north, and the Bannockburn from the south. The tide, which flows a little above Stirling, renders it navigable to that town for vessels of 70 tons. Below Stirling the river winds in a remarkable manner across its valley, making so little progress, that, following its course to Alloa, the distance from Stirling Bridge is about 16 miles, while in a direct line it is scarcely seven. These windings are called the *Links* of the Forth. Two miles above Alloa it receives the Devon from the north-east. Below Alloa it expands into the large estuary called the Firth of Forth, which washes the north-eastern side of the county, till it meets with Linlithgowshire, a little to the south of Grangemouth. Next in importance, and the only other stream worthy of particular notice, is the Carron, which, rising in the interior, pursues an easterly course, and joins the Firth of Forth at Grangemouth. It is navigable for vessels of 200 tons as far as the village of Carron Shore, the shipping place of the Carron Company, nearly two miles from its confluence with the Forth. Besides Lochlomond, of which the greater part is in Dunbartonshire, several small pieces of water occur in different parts, none of them remarkable. Salmon are caught in the Forth, and also in Lochlomond, and in 1839 the fishery afforded a revenue of L.650 a year to the town of Stirling. Formerly the salmon-fishings were let as high as L.1400, part of which belonged to another proprietor.

Valuation and rental.

The valued rent of Stirlingshire is L.108,509. 3s. 3d. Scots, and the real rent of the lands and houses in 1815 was L.218,761 sterling. In 1811 the number of estates was 147, of which 109 were below L.500 Scots, and only nine above L.2000 of valuation, thus indicating that the landed property was much divided; and not a fourth of the whole was entailed, a smaller proportion than in most parts of Scotland. The estates of the duke of Montrose, Lord Dundas, Sir Charles Edmonstone, Mr Forbes of Callendar, Mr Murray of Polmaise, the principal proprietors, are rented at from L.6000 to L.14,000, and several others are worth from L.1000 to L.4000 a year; but the greater number are below L.1000. Some of the proprietors have increased the value of their estates by means of embankments on the Firth of Forth. Several hundred acres, many of them worth as high a rent as any in the county, have thus been reclaimed and brought into cultivation, and a great deal more may be gained in the same manner. All the small proprietors, and most of the great ones, reside upon their estates; and several of the latter occupy considerable farms of their own, which they have improved, and continue to cultivate in a very judicious manner. There is accordingly a great number of seats over all the lower parts of the county. Before the union between Scotland and England, considerable tracts were granted to the retainers and dependants, or the tenants, of the principal proprietors, and their heirs, for ever; subject only to the payment of the rent of those times, which is now very trifling. These are called *feuurs* or *portioners*, and in some parishes, especially Denny, form a pretty numerous class.

Wood-lands.

There is a good deal of both natural and planted wood in Stirlingshire, about 13,000 acres of the former, and 10,000 of the latter; and much of the former, in the state of coppice, has long yielded a regular income to the proprietors, little if at all inferior to the average rent of the arable land. The Buchanan woods, belonging to the duke of Montrose, seem to be under very regular management, being divided into twenty-four *hags* or portions, of which one is cut every year. About twenty-five years ago, this produced from L.16 to L.24 the Scots acre, after leaving a number of *reserves* to stand for timber. Every acre gives at a medium about one ton and a half of bark, which, during the late war, sold at L.18; and the small timber generally pays expenses. This does not now hold true, as bark does not bring above L.7. Much of the land on which this wood grows is of little value

for any other purpose; not worth half a crown an acre. On the same estate, and also in other parts of the county, extensive plantations have been formed within the last seventy years.

Stirling-shire.

The mountainous parts of Stirlingshire are occupied with sheep of the black-faced or heath breed, but of late years many Cheviot and other breeds have been introduced; and the lower hills by Highland cattle; and there the farms are necessarily of considerable extent. The arable land, however, is for the most part divided into small farms, especially the Carse lands on the Forth, where the general size does not exceed from 40 to 100 or perhaps 120 acres.

The agriculture of this county, which a few years ago was in a very inferior condition, is now (1840) in the highest state of improvement. Stirlingshire farmers and farm-servants are anxiously sought after in every part of the united kingdom. Landed proprietors even in East Lothian and Berwickshire, where farming had long been managed in a very spirited manner, and with decided success, have latterly confessed that an inoculation of Stirlingshire farming would prove highly beneficial to the agriculture of those counties. For the attainment of this confessed superiority, Stirlingshire is indebted to a variety of favourable circumstances, to which we shall now shortly advert in quite a practical manner, as the theory has already been submitted to our readers in the article upon AGRICULTURE. Among these circumstances may be chiefly noticed the Deanston or thorough-draining system, the subsoil or deep ploughing system, and the encouragement given to both by many of the landed proprietors. But before proceeding to state these circumstances, we may premise, that had not the farmers in this county been morally prepared to admit innovation, and to follow good example, these improvements, like many others equally beneficial in various departments of practical knowledge, must have fallen to the ground, to be again resuscitated and pressed upon public attention in more auspicious times. It is therefore to the zeal and indefatigable industry, stimulated by enlarged notions alike of public and private interest, and exercised by Stirlingshire farmers, that we and the whole empire have to congratulate ourselves upon those immense improvements in agriculture, which are enabling a small, and, generally speaking, a sterile country, to support a rapidly increasing population, while at the same time we regret to add, that those very farmers are, notwithstanding these improvements, scarcely able to maintain their position, in consequence of the depreciated and still depreciating value of the products of arable husbandry.

This admirable system, which was either invented by Mr Deanston Smith of the Deanston Works, or by him carried to the highest state of perfection, consists in running longitudinal cuts or drains to the depth of three feet, or at least two and a half, parallel to the ridges of the field, taking care that at the lower extremity they all terminate in a main drain running at right angles to the other drains, and which must at least be six or twelve inches deeper than the longitudinal or proper drains for the field. This cross drain is technically called the "main;" and, besides its greater depth, it should otherwise be more capacious, that it may with ease carry off the accumulated waters of the whole or greater part of the field. When the farm is drained wholly at the expense of the farmer, the main is frequently left open, although he incurs a considerable loss of ground, and some expense annually for clearing it out. The best mode of covering is to form an arch both below and above, or, in other words, make a cylinder of it. The building may be either with or without mortar; but with mortar it is much more durable, and leaves a smoother run for the water. The drain or main is sometimes covered with flag-stones, and soil to the depth of eighteen inches laid over all, bringing it to the level of the field; and so nothing is lost, but something gained. It must however be confessed that this pro-

Live stock.

or thorough draining system.

Stirling-shire.

cess is too expensive for a tenant. With respect to the longitudinal drains, they ought, as already stated, to be at least three feet or two and a half deep, and from three to six inches wide at the bottom. If upon dry-field ground, where stones can easily and cheaply be procured, they are then filled to the height of from nine to twelve inches, with the stones broken so small as to pass through a ring of two and a half inches in diameter. They are then covered with sod having the grassy side under, or, when sod cannot be procured, with damaged hay or straw, old thatch, ferns, or even roots of quickens (*triticum repens*), saved for the purpose in cleaning the same and other fields of the farm. Over these looser materials, care must be taken to spread a layer of soil of a few inches in depth, which must be trodden down and well compacted together, that it may serve as a permanent close cover to the looser materials below, to prevent the crumbling and loose soil from dropping in among the small stones, and thus preventing the run of the water. Simple as this mode of covering is, it has hitherto been found to answer the purpose effectually; as some drains at Deanston constructed in this manner fifteen years ago are still as efficient as at first. These various preparations must not be raised higher than half the depth of the cut, as the superincumbent soil, to meliorate which all this labour has been undertaken, has now to be thrown in; and it must have an average depth of eighteen inches, in order that the subsoil-plough, in traversing the field, may not by any possibility injure the drain.

Expense.

The expense of this mode of draining is very considerable, and has in most cases been deemed beyond the means of ordinary farmers, without some stipulated aid from their landlords. This we believe to be far the best way of managing so expensive an improvement; because the practical farmer, when the operations are entirely left to himself, will devise expedients for lessening expense, in direct outlay at least, of which expedients the landlord could not be supposed to avail himself. In some cases the drains must be distant from each other only ten feet. This is the most expensive system that has hitherto been thought necessary, even upon the wettest land or the most tenacious bottom. The other extreme is at the distance of forty feet, which is deemed sufficiently wide for any land that requires draining; and there is little in Scotland, except what is incumbent upon pure sand or fine gravel, which draining may not improve. It is thus evident that the expense of draining each acre must depend upon circumstances. We shall give Mr Smith's calculations, which we believe not to be overrated where every thing has to be paid for in money. It is unnecessary to give the whole table: it will be sufficient to state the expense at ten, twenty, thirty, and forty feet distance between the cuts. At ten feet between the cuttings, where the subsoil is an obdurate till, almost if not altogether impervious to water, the cost will amount to L.12; at twenty feet, which implies sandy clay partially pervious to water, L.6; at thirty feet, which implies a free open stony bottom, L.4; at forty feet, which implies the most open bottom or subsoil requiring draining, L.3. These sums, especially the first two, are large, but not larger than the work can actually be done for in money value; nor are they too great for the benefit to be derived from such judicious outlay; for if the work be properly executed, experience has not yet taught the real benefit which may be derived from such efficient drainage, nor how long it will endure in an effective state.

Outlay to a practical farmer.

The actual outlay to a practical farmer, who calculates nothing but the cutting of the drains, breaking the stones, and putting them into the drains, his own people gathering the stones which are found in the field, carting them, and

filling up the remaining part of the cuts, so as to bring the field to its proper level, for which he estimates no charge, the labour being performed by the force upon the farm, amounted to L.2. 14s. the acre. This was only eightpence more upon the acre than the sum stated in Mr Smith's table for the distance of thirty feet between the drains, which was the scheme executed by the farmer referred to upon a field of thirteen acres since last autumn, and which field afterwards produced an excellent green crop of potatoes and turnips. Here then is an admirable example of what may be accomplished by an active and enterprising farmer, wholly at his own expense, and without losing either the whole or any part of a crop. This was accomplished upon the farm of Bearside, near Stirling, the property of William Murray, Esq. of Touchadam and Polmaise, and possessed by Mr James Gray, whose active and enlightened industry is rapidly converting a piece of moorland, which some years ago bore only an unprofitable crop of tall furze, affording shelter to some scores of rabbits, into one of the most valuable farms upon the Polmaise estates. He has been busily engaged upon the same laborious task for the last six years, and two or three more will complete the object which he has in view. He may then with confidence rely upon his expense and toil being rewarded.¹ When stones have to be quarried and carted a greater distance, the expense will be somewhat greater.

Stirling-shire.

When stones cannot be procured in sufficient quantity, Draining or at moderate expense, recourse is had to tiles made for with tiles. the purpose. The accompanying figure represents a section of the tile . They are about five inches deep and

four across, and generally fourteen inches long; and in most cases flat tiles are placed in the bottom of the drain, and the arched ones placed over them; but where the subsoil is very stiff, the extra expense of sole tiles is dispensed with. As draining with tile is the cheapest mode in clayey land, such as the Carse in Stirlingshire, and with stones as described above in dry-field, and as the filling-in process in both is the same, it is needless to repeat the description already given. With respect to the comparative merits of the two modes, the most competent judges prefer the small stone-drains, when at all practicable, to those formed with tile, both as concern durability and practical utility. Certain it is, they possess one decided advantage over tile, as they present a perfect barrier to the admission of vermin, as moles, rats, &c. and therefore the chances of being choked by the ravages of these noxious animals are greatly diminished, and the durability increased. It may be useful to add, that "the frequent drain system" is another appellation by which it is pretty generally known.

Not satisfied, however, with this expensive system of Subsoil draining, Mr Smith of Deanston has had recourse to a system of ploughing invented by himself, and denominated, aptly enough, "subsoil-ploughing." The implement by which the work is accomplished, is just like any other old Scottish plough, without a mould, but larger, heavier, and stronger. It is never wrought with fewer than three, most commonly with four, and not unfrequently with six horses, according to the nature of the soil in which it has to operate. Where it is desirable to bring up any of the subsoil, this is performed by another large plough, called a "trench-plough," which has a mould attached to it like an ordinary plough, and is generally drawn by three horses. The mode of procedure consists in an ordinary plough with two horses going before it, with the usual depth of furrow, the subsoil-plough following with a depth of at least ten or even twelve inches more, and forcing to the surface, besides

¹ To some it may appear invidious to select the names of individuals, when so many are at least equally active in improving. It will serve as our apology, that some names were absolutely necessary to verify our statements; and Mr Murray took the lead as a landlord in introducing these improvements, while among the tenantry Mr Gray has not been the least active.

Stirling-shire.

stirring the soil below, whatever stones of the weight of not more than four hundredweight it may encounter in its progress. When stones exceed the above weight, a lad following the plough marks their situation with a tally, that they may afterwards be removed with crowbars. These, with others found upon the surface, are the stones with which the drains are filled; and thus, while the drains serve as leaders for conveying the water away when collected, the thorough stirring of the subsoil permits a more rapid percolation, and also evaporation, by which the ground becomes very speedily dry, and consequently much better fitted for the reception and nourishment of seed of every kind. The expense of subsoil-ploughing, when paid in money, generally varies from 24s. to 30s. the acre; but it is now becoming a part of the routine labour of the farm. Supposing it, however, to be contracted for, and paid in cash, the extra expense does not exceed one fifth of the cost of trenching with the spade, and yet the work is as effectually done. The reader ought to remember, that the calculations are adjusted to the Scotch acre, and that four Scotch are equal to five statute acres; so that the amount of money required to execute four Scotch, will cover the expense of five imperial acres.

Expense.

Beneficial results of these improvements.

In noticing this part of the subject, we shall first copy two short extracts from a writer in the Quarterly Journal of Agriculture for June 1839, pp. 69 and 70. Speaking principally of the draining, he says, "This so great benefit, not for Scotland only, but for the whole kingdom, is as yet in its infancy. Already the fame and the utility of it is spreading all over the island; and we have not a doubt, in a short time, there will not be found a spot that has not been made anew by means of this simple yet powerful and efficient system of draining....It is perfectly wonderful to behold the mighty change this thorough-drain system is making in the different parts of the country where it is in operation. Wet land is made dry, poor weeping clays are converted into turnip-soil, and even what would formerly have been accounted dry is advanced in quality. Whole parishes in the vicinity of Stirling are completely transformed from unsightly marshes into beautiful and rich wheat-fields; and where the plough could scarcely be driven for slush and water, we see heavy crops per acre, and heavy weight per bushel, the quantity and the quality alike improved." But these statements, although true, and in no degree exaggerated, are yet of too general a nature to fix the attention of the reader. We shall therefore simply state two facts, which are well authenticated, as illustrative of the beneficial results of these decided improvements in agriculture. In the Carse, which have been cultivated from time immemorial, and have always been very productive, and which have sometimes been considered beyond the reach of improvement, the most distinct improvement is visible even in the best years; and in wet seasons the condition of the crop is still more distinctly marked for the better. In the driest seasons it is not beyond the truth to say, that the crop is larger from a sixth to a fourth, and the quality vastly improved in weight and fineness, while in wet and cold seasons, such as 1838 and 1839, it is impossible to estimate the value of these admirable improvements. Again, with respect to the other kinds of soil in Stirlingshire, namely, the dry-field, our remarks must be understood to apply less generally, as the soil is not so uniformly good; yet are the effects more decisively manifested here than in the Carse, as in wet seasons, without the draining and subsoil-ploughing, many fields would scarcely carry any crop at all, and so both seed and labour would be lost. The following statement may be received as applicable to many different instances of management. A small field of seven Scotch acres had during sixteen years of a nineteen years' lease produced upon an average the sum of from 10s. to 15s. the acre as its whole return. At this period, when the farmer felt himself secure in the prospect of another lease, he drain-

ed the ground at intervals of only fifteen feet, in consequence of the great wetness of both the active and subsoil. It was then subsoil-ploughed, and covered with a crop of potatoes and turnip. This was in 1836, a very wet season. The product was a good fair crop of both. In 1837 it was sown with barley, and produced the heaviest crop of that grain that had hitherto been produced on the farm. This yielded more pounds per acre than it had formerly given shillings. In 1838, although an exceedingly bad season, it yielded fully two tons of hay per acre; and in the ensuing year, although only seven acres in extent, it produced more food to the same number of milk-cows than thirteen acres of an undrained field did in the preceding year. As these were the first crops after being drained, there is reason to believe, that when again subjected to tillage after pasture it will be still more productive, as the drains will have had more time thoroughly to dry the field. Many such instances of beneficial influence could easily be pointed out in dry-field farming, but this would only be a useless repetition. It is pertinent enough to add, that not only are the crops improved, but both the seed-time and the harvest are rendered earlier than formerly; a circumstance of vital interest in the upland districts, where, under the ordinary modes of culture, it has not unfrequently been difficult, and sometimes impossible, to get the corn to ripen at all in wet seasons, which so frequently occur in our climate.

The encouragement of the landlords, most of whom are resident in this county, has been prompt and judicious, especially in patronising the introduction of the draining system, which is the basis of modern agriculture. Decidedly the most active of these were Mr Murray of Polmaise, the late Mr Graham of Airth, and Mr Moir of Leckie, who were among the first to direct their attention to this subject, and who effectually introduced the new system among their tenantry, and thus obtained for it a fair field. Since then its advantages have been so manifest as to induce the most prejudiced and stubborn of the farming population to adopt it to a greater or less extent. Nor has any popular clamour ever been raised against the improved culture; a proof that even the rural population are beginning to admit new ideas.

Another circumstance which has risen out of this improved agriculture, is the establishment of Drummonds Agricultural Museum; an institution which, while it may be called the offspring of the improved culture, has yet had a very beneficial effect in promoting the objects which gave rise to it. It was begun in the year 1831 by the Messrs Drummond, the spirited seedsmen in Stirling, and was founded, and for the first two or three years conducted, at their own expense. The gentlemen, and some of the more public-spirited of the farmers, of the district, have since contributed so much towards its expense, that the public are now admitted gratis. It is still, however, the Drummonds Museum, and they are at this moment building large premises for containing it and their own business establishment. The principal object contemplated by this museum is the collecting together under one view practical working specimens of every possible, or at least known implement, connected with agriculture, from the twisting of a straw-rope to the ponderous draining plough, the invention of Mr Macewan, farmer at Blackdub, near Stirling, and which is drawn by twelve horses. Few persons, even of those who are most conversant with the details of agriculture upon the most extensive and complicated scale, could have the slightest idea of the immense variety of implements here exhibited, both for show and sale. To specify particulars would answer no purpose. Besides the implements, there are also specimens of every kind of grain, root, or fruit, which will bear exhibition, along with soils, sections of drains, corn and hay stacks, amounting in all to between six and eight thousand specimens; and few weeks pass without additions being made to the number. It is only fair to

Stirling-shire.

Drummonds Agricultural Museum.

Stirling-shire. add, that the landlords and farmers of the adjoining counties of Perth and Clackmannan, which, although politically separated, form only one district, the basin of the Forth, have as promptly availed themselves of these improvements as those of Stirlingshire.

Deer. The land on the banks of the Forth is exceedingly well adapted for orchards, of which there are a few, but of no great extent. The island of Inchmurrin, in Lochlomond, the property of the duke of Montrose, has been stocked with fallow deer for more than a century, the number being about 240, which are properly attended to, and kept always in a thriving condition.

Manufac-tures. The manufactures are carpets, tartans, plaid-shawls, trouser-stuffs, and other woollens, in the town of Stirling, but more in the neighbourhood. These within the last ten years have increased in nearly a tenfold degree, so that this district has now become one of the principal seats of the woollen manufacture in Scotland, and promises soon to take the lead. Paper, cottons, alum, copperas, soda, Prussian blue, &c. are produced on an extensive scale; spirits at several large distilleries, the amount of duty from home-made spirits being greater than in any other district in Scotland; and iron goods at Carron. The Carron Works, celebrated over all Europe, were established upon the banks of the river of that name about eighty years ago, by Dr Roebuck and Messrs Cadell and Garbet, who were joined in the undertaking by several other gentlemen. By the charter of the company, they are authorized to employ a capital of L.150,000, which is divided into 600 shares; and ten of these are required to give a vote in the management. During the late war they employed upwards of 2000 able-bodied men, and paid in wages above L.120,000 yearly; and this is nearly true at the present day. At these works all sorts of cast-iron goods are made, and also bar-iron, said to be equal to the Russian, but particularly cannon, and that kind called carronades, which having been invented here, take their name from the works. The boring of the cannon is a very interesting operation, which is performed in about forty-eight hours, by machinery moved by water. One of their engines raises upwards of thirty tons of water in a minute; and so extensive are the works, that they are said to consume every day about 200 tons of coals. They have water-carriage from the Firth of Forth by means of the Carron, and to the Firth of Clyde by the Forth and Clyde Canal, which passes through the district a little to the south of the Carron. The number of vessels in the London trade alone is seven, and about as many more are constantly trading to other places.

Falkirk foundery. Some years ago another extensive foundery was projected, and it is at present in operation upon a respectable footing, manufacturing goods equal to those of Carron.

Commerce. Notwithstanding the favourable situation of Stirlingshire, on a navigable river, and between the east and west seas, which for many years have been connected by a canal, it has but a small town-population, and till lately its commerce was inconsiderable. Even now, half its exports, not including its agricultural produce, is supposed to be furnished by the Carron Works. In consequence of the increase of the woollen manufacture, commerce must necessarily be increased also. The principal town is Stirling, containing, in 1831, 8556 inhabitants; a place of great antiquity, which, though situated on the navigable part of the Forth, has little trade by water, and is chiefly indebted for its importance to its situation on the confines of the Highlands. Falkirk, on the eastern side of the county, a little to the south of the Forth and Clyde Canal, had a population, including a large and populous parish, in 1831, of 12,743, and is distinguished for its great fairs or trysts, which are held on the second Tuesday in August, September, and October, where cattle, sheep, and horses are brought for sale to the annual value of L.650,000. Grangemouth,

founded by Sir Laurence Dundas in 1777, on the angle formed by the junction of the Carron and the Forth and Clyde Canal, is now a considerable town, and the principal seaport of the county. Its trade is chiefly with the north of Europe and along the east coast. It has a custom-house, a dry dock, and other necessary works. The depth of water in the harbour is generally, in spring tides from sixteen to eighteen feet, and in neap tides from ten to twelve. The only other towns are Kilsyth, Bannockburn, Denny, Campsie, and Balfron. On the east side there is a number of small villages, occupied partly by agricultural labourers and mechanics, and partly by weavers employed by the Glasgow manufacturers.

Besides the Forth and Clyde and Union Canals, the Edinburgh and Glasgow Railway, now constructing, passes through this county, in a direction nearly parallel to the canals, and must be productive of great benefit to its population.

The county, which in 1831 had only 118 freeholders, has now a constituency of 2332, who send one member to parliament. Stirling, its only royal borough, is associated with Culross, Dunfermline, Inverkeithing, and Queensferry, in the elections for the Scottish burghs; and Falkirk, a parliamentary borough, with Airdrie, Hamilton, Lanark, and Linlithgow; Stirling and Falkirk being both the returning burghs. A poor-rate is only levied in a few parishes, the poor being chiefly supported, as in most parts of Scotland, by voluntary contributions.

Stirlingshire exhibits remains highly interesting to the antiquary, and has been the scene of some of the most remarkable events in Scottish history. The Roman wall, called the Wall of Antoninus, and vulgarly Græme's Dyke, which traversed this county, may still be traced in several places. The battles of Stirling, in which Wallace defeated the English under Warren earl of Surrey; of Falkirk, in which he in his turn was defeated; of Bannockburn, which secured the independence of Scotland; of Sauchie-burn, between James III. and his rebellious subjects, in which the former was defeated, and was afterwards treacherously slain at Milton; were fought in this county. Stirlingshire was in former days the battle-ground of Scotland. Here we may refer to Nimmo's History of Stirlingshire, Ray's Military Antiquities, and Chalmers's Caledonia.

The population of Stirlingshire, according to the census of 1801, was 50,825, in 1811 it amounted to 58,174, in 1821 to 65,376, and in 1831 to 72,600. The increase of population from 1811 to 1831 was 21,775. (D. E.)

STIRRUP, in the manège, a rest or support for the horseman's foot, for enabling him to mount, and for keeping him firm in his seat. Stirrups were unknown to the ancients. The want of them in getting upon horseback was supplied by agility or art. Some horses were taught to stoop to take up their riders; but the riders often leapt up by the help of their spears, or were assisted by their slaves, or made use of ladders for the purpose. Gracchus furnished the highways with stones, which were intended to answer the same end. The same was also required of the surveyors of the roads in Greece, as part of their duty. Menage observes that St Jerom is the first author who mentions stirrups. But the passage alluded to is not to be found in his epistles; and if it were there, it would prove nothing, because St Jerom lived at a time when stirrups are supposed to have been invented, and after the use of saddles. Montfaucon denies the genuineness of this passage; and, in order to account for the ignorance of the ancients with regard to an instrument so useful and so easy of invention, he observes, that while cloths and housings only were laid upon the horses' backs, on which the riders were to sit, stirrups could not have been used, because they could not have been fastened with the same security as upon a saddle. But it is more probable, that in this instance, as in many others, the

Stiviere
||
Stock-
holm.

progress of human genius and invention is uncertain and slow, depending frequently upon accidental causes.

STIVIERE, a market-town in the delegation of Mantua, in Austrian Lombardy, usually distinguished by the name Castiglione della Stiviere. It stands in a strong position, and has a castle, eight churches, and 5460 inhabitants; and is remarkable for the victory of the French over the Austrians in 1796. Long. 10. 47. E. Lat. 45. 42. N.

STOBÆUS, JOANNES, whose compilations have been found so highly valuable, is supposed to have been born at Stobi, a city of Macedonia. Heeren has endeavoured to render it probable that he must have lived between the years 450 and 500. He does not appear to have been a Christian. From about five hundred writers, in verse as well as prose, he extracted and digested an immense collection of passages; which has most commonly been considered as one work divided into four books, the first two being described as "*Eclogæ Physicæ et Ethicæ*," and the other two as *Sermones*. But, according to Heeren, they constitute two distinct compilations. As many of the books quoted by Stobæus have scarcely left any other vestiges behind them, his merit in preserving these numerous and variegated reliques of antiquity cannot well be too highly estimated. Of the third and fourth books, otherwise called the *Florilegium*, the Greek text was published by Victor Trincavelus, Venet. 1536, 4to. An edition, accompanied with a Latin version, was published by Conrad Gesner, Tiguri, 1543, fol. It was reprinted at Basel in 1549, and at Zürich in 1559. Other editions succeeded; but they have all been nearly superseded by that of Gaisford, Oxon. 1822, 4 tom. 8vo. The text, which has been adjusted with great industry and skill, is not accompanied with a Latin translation. Of the "*Eclogarum libri duo*," the Greek text was first published together with a Latin version by Canter, Antverp. 1575, fol. The editor made use of two manuscripts belonging to Sambucus and Sirlet; and hence a certain bibliographer has described this as Sirlet's edition. A valuable edition of the *Eclogæ* was long afterwards published by Heeren, Gottingæ, 1792-4, 2 tom. 8vo. The *Florilegium* and the *Eclogæ* had been published in the same volume, under the title of "*Stobæi Sententiæ, ex thesauris Græcorum delectæ*." Lugduni, 1608, fol. Some copies have a new title, with the date of 1609. Here we must not overlook the elegant labours of Grotius: "*Dicta Poetarum quæ apud Stobæum exstant, emendata, et Latino carmine reddita*." Paris. 1623, 4to.

STOCKBRIDGE, a town of the hundred of King's Somborne, in the division of Andover, in the county of Hampshire, 66 miles from London. It stands in a pleasant valley, with various streams running through it, which afford great sport to parties who repair to them to enjoy trout-fishing. It is an ancient borough, and returned two members to parliament till 1832, when it was disfranchised. It has a small market on Thursday. The inhabitants amounted in 1801 to 643, in 1811 to 663, in 1821 to 715, and in 1831 to 851.

STOCKHOLM, the capital of the kingdom of Sweden, stands in the centre of the province of that name. It is built on two peninsulas, and several islands of different dimensions, which are connected by numerous bridges and ferries, and, including the water, is of great extent, being two and a quarter miles in length, and near two miles in breadth. A great part of this enclosure is not covered with houses; and in many parts the rocks are interspersed among patches of land and gardens, so as to give it an appearance very different from that of any other of the European capitals. The whole is divided into ten districts, the most important of which, called the city (*Stadt*), is small but interesting, from being the residence of the higher classes of the inhabitants, and the site of the most prominent buildings. In this division the streets are narrow, dark, and badly

paved. They run parallel to each other, and are united by cross streets; but in all of them the gutters in the middle are very repulsive to more than one sense. The houses however are large, firmly built, and not destitute of taste. The royal palace is of colossal dimensions, and erected in a noble style of architecture. Being rather elevated, it commands a view of the whole city on one side, and is surrounded with tasteful gardens on the other. Within it is contained the presence-chamber, the royal museum, a library of 30,000 volumes, the collection of the Swedish academies, a square with a monument and figure of Gustavus III., and the German church, with a tower of 120 feet in height. In the same part are also the exchange, the bank, the cabinet of coins and medals, the mint, the college of mining, and the town-hall. The royal stables are in another division. On one of the islands, forming a district, are the naval storehouses, and the hall of the admiralty. On another island, also a district, is a fort with twelve cannon and a lazaretto. On many of these districts, though each has some good buildings, the others are poor wooden houses, without taste or ornament, and destitute of cleanliness. The city is under the government of a stadtholder, with inferior officers; and under the police are organized bodies of watchmen and firemen. Here both the civil and the criminal courts are held. The ecclesiastical affairs are managed by the consistory, with a superintendent as president. Under it are fourteen pastorates of the Lutheran religion; and there are besides places of worship for German and French Calvinists, for Catholics, and for Finnish Lutherans. There are many schools both for elementary and classical learning, and also an academy of sciences, with an astronomical observatory, a society of antiquaries, and other bodies for promoting the different branches of knowledge. There are abundance of benevolent institutions, adapted to alleviate the various calamities to which mankind are subject, but especially hospitals for seamen and widows. Stockholm is the chief manufacturing place of the kingdom, and supplies silk, woollen, and cotton clothing, much linen, and also refined sugar, tobacco and snuff, pottery and china ware, glass, jewellery, brandy, and many smaller articles, but almost exclusively for domestic use. It is also the chief mart of foreign trade, to which the excellence and security of its harbour greatly contributes. About 500 or 600 vessels, of different burdens, are yearly despatched. Some of these arrive with cargoes of corn, but many in ballast. They are loaded with the excellent iron of Sweden, with copper, tar, pitch, anchors, nails, cannon, bar-steel, planks, masts, cordage, hides, leather, tiles, and in some years a large quantity of preserved herrings. The city has establishments for recreation in two theatres, several public walks, and a variety of clubs and other social assemblies. The population has been fluctuating. In 1795 it amounted to 74,378, in 1800 to 75,511, in 1805 to 72,652, in 1814 to 62,830, in 1818 to 65,474, in 1826 to 77,273, in 1832 to 79,526. Long. 17. 59. 30. E. Lat. 59. 19. 15. N.

STOCKING, that part of the clothing of the leg and foot which immediately covers and screens them from the rigour of the cold. Anciently, the only stockings in use were made of cloth, or of milled stuffs sewed together; but since the invention of knitting and weaving stockings of silk, wool, cotton, thread, &c. the use of cloth stockings is quite discontinued. Dr Howell, in his *History of the World*, vol. ii. p. 222, relates, that Queen Elizabeth, in 1501, was presented with a pair of black knit silk stockings by her silk woman, and thenceforth she never wore cloth ones any more. The same author adds, that King Henry VIII. ordinarily wore cloth hose, except there came from Spain, by great chance, a pair of silk stockings. His son, King Edward VI., was presented with a pair of long Spanish silk stockings by Sir Thomas Gresham, and the present was

Stockport. then much taken notice of. Hence it should seem that the invention of silk knit stockings originally came from Spain. Others relate, that one William Rider, an apprentice on London Bridge, seeing at the house of an Italian merchant a pair of knit worsted stockings from Mantua, took the hint, and made a pair exactly like them, which he presented to William earl of Pembroke, and that they were the first of that kind worn in England, anno 1564.

The modern stockings, whether woven or knit, are formed of an infinite number of little knots, called *stitches*, *loops*, or *meshes*, intermingled in one another. Knit stockings are wrought with needles made of polished iron or brass wire, which interweave the threads and form the meshes of which the stocking consists. At what time the art of knitting was invented, it is perhaps impossible to determine, though it has been usually attributed to the Scots, as it is said that the first works of this kind came from Scotland. It is added, that it was on this account that the company of stocking-knitters established at Paris in 1527 took for their patron St Fiacre, who is said to have been the son of a king of Scotland. But it is most probable that the method of knitting stockings by wires or needles was first brought from Spain.

Woven stockings are generally very fine. They are manufactured on a frame or machine made of polished iron, the structure of which it is needless to describe, as it may be seen in almost every considerable town in Great Britain. The invention of this machine is, by Mr Anderson, attributed to William Lee, M. A. of St John's College, Cambridge, at a period so early as 1589. Others have given the credit of the invention to a student of Oxford at a much later period, who, it is said by Aaron Hill,¹ was driven to it by dire necessity. This young man falling in love with an innkeeper's daughter, married her though she had not a penny, and he by his marriage lost a fellowship. They soon fell into extreme poverty; and their marriage producing the consequences naturally to be expected from it, the amorous pair became miserable, not so much on account of their sufferings, as from the melancholy dread of what would become of their yet unborn infant. Their only means of support was the knitting of stockings, at which the woman was very expert. "But sitting constantly together from morning to night, and the scholar often fixing his eyes, with stedfast observation, on the motion of his wife's fingers in the dexterous management of her needles, he took it into his imagination that it was not impossible to contrive a little loom which might do the work with much more expedition. This thought he communicated to his wife, and joining his head to her hands, the endeavour succeeded to their wish. Thus the ingenious stocking-loom, which is so common now, was first invented; by which he did not only make himself and his family happy, but has left his nation indebted to him for a benefit which enables us to export silk stockings in great quantities, and to a vast advantage, to those very countries from whence before we used to bring them at considerable loss in the balance of our traffic."

STOCKPORT, a town in the hundred of Macclesfield and county of Chester, 173 miles from London. It stands on the banks of the river Mersey, over which is a neat stone bridge of a single arch, resting on rocks on both sides. By means of a canal this town has water communication with the rivers Dee, Ribble, Trent, and Severn, and thus with the greater part of the kingdom. The trade which it carries on is very extensive. It was formerly confined in a great measure to making cotton goods; but of late years the silk-manufacture has been introduced, and has been prodigiously extended. There are two parish churches. The oldest, called the Red Church, is built on a solid rock, and has a neat square tower, with a good set

of bells. There are also many places of worship for the various dissenting sects. By the act of 1832 it has been created a borough, and returns two members to the House of Commons. There is a large market on Fridays. The inhabitants amounted in 1801 to 14,830, in 1811 to 17,545, in 1821 to 21,726, and in 1831 to 25,469.

STOCKS, or **PUBLIC FUNDS** in *England*. See **FUNDING SYSTEM**.

STOCKTON, a town in the ward of that name, in the county of Durham, 248 miles from London. It stands on the river Tees, which is navigable to it; and consists principally of one well-built, long, and wide street, in which is the church, the town-hall, and grammar-school. It is an ancient borough, governed by a mayor, a recorder, and aldermen, but elects no members to the House of Commons. It formerly contained a castle, which has been demolished, and the stones applied to the erection of more modern buildings. The bridge over the Tees is an elegant object. The inhabitants carry on a considerable trade in making coarse linens, huccabacks, table-cloths, and sail-cloths; and several ships are built on the river. Stockton is well supplied with coals, vegetables, fruit, fish, and other necessaries; and it has a market on Wednesday and another on Saturday. The number of inhabitants amounted in 1801 to 4009, in 1811 to 4229, in 1821 to 5006, and in 1831 to 7763.

STOKESLEY, a town in the north riding of the county of York, and in the wapentake of Langborough. It is 242 miles from London, and forty-three from York. It stands on the river Leven, and consists of one well-built, long street, with no remarkable building except the manor-house, adjoining to the churchyard, which at an early period was granted to Guy de Baliol, whose family came to England with William the Conqueror. The town depends on the fertility of the land around it, from which a market on Saturday is well supplied. The parish comprises four small townships. The population amounted in 1801 to 1755, in 1811 to 1759, in 1821 to 2290, and in 1831 to 2376.

STOICS, the name given to a sect of Grecian philosophers, from *Στοα*, the porch in Athens, which the founder of the sect chose for his school.

STOLE, a sacerdotal ornament worn by the Romish parish priests above their surplice, as a mark of superiority in their respective churches; and by other priests over the alb, at celebrating of mass, in which case it goes across the stomach; and by deacons over the left shoulder, in the form of a scarf. The stole is a broad swath, or slip of stuff, hanging from the neck to the feet, and is marked with three crosses.

Groom of the STOLE, the eldest gentleman of the king's bedchamber, whose office it was to present and put on his majesty's first garment, or shirt, every morning, and to order the things in the chamber.

STOLPE, a town of Prussian Pomerania, in the government of Koslin, the capital of a circle of the same name. It stands on the river Stolpe, which is navigable to it. It contains 650 houses, with 6983 inhabitants in 1834, who are chiefly employed in linen and woollen manufactures, in fisheries on the river for salmon, and in distilleries and breweries. Long. 16. 50. E. Lat. 54. 27. 29. N.

STONE, a town in the hundred of Pirehill and county of Stafford, 141 miles from London. It is pleasantly situated on the banks of the river Trent, is neat and well built; and by means of a canal has an easy communication with most parts of the kingdom. The church is a fine structure, with a square tower and a good set of bells. The inhabitants amounted in 1801 to 2305, in 1811 to 2314, in 1821 to 2855, and 1831 to 3460.

Stockton
||
Stone.

¹ See an Account of the Rise and Progress of the Beech Oil Invention, &c. 8vo, 1715.

Stone
Edmund
||
Stone-
haven.

STONE, *Edmund*, a distinguished self-taught mathematician, was born in Scotland, but neither the place nor the time of his birth is well known; nor have we any memoirs of his early life, except in a letter from the Chevalier Ramsay to Father Castel, a Jesuit of Paris, and published in the *Mémoires de Trevoux*. Born the son of a gardener of the Duke of Argyle, he arrived at eight years of age before he learned to read. By chance a servant having taught him the letters of the alphabet, there needed nothing more to discover and expand his genius. He applied himself to study, and arrived at the knowledge of the most sublime geometry and analysis, without a master, without a conductor, without any other guide but pure genius. He was author and translator of several useful works, viz. 1. A New Mathematical Dictionary, in 8vo, first printed in 1726. 2. Fluxions, in 8vo, 1730. The Direct Method is a translation from the French of De l'Hospital's "Analyse des infiniment Petits;" and the Inverse Method was supplied by Stone himself. 3. The Elements of Euclid, in 2 vols. 8vo, 1731. Stone was a fellow of the Royal Society, and had inserted in the Philosophical Transactions (vol. xli. p. 218) an "Account of two species of lines of the 3d order, not mentioned by Sir Isaac Newton or Mr Stirling." In 1758 he published "The Construction and principal Uses of Mathematical Instruments; translated from the French of M. Bion. In 1742 or 1743 his name was withdrawn from the list of the Royal Society; and in his old age he appears to have been left to poverty and neglect. He survived till March or April 1768.

STONE, *Jerome*, the son of a seaman, was born in the parish of Scoonie, Fifeshire. His father died abroad when he was but three years of age, and his mother, with her young family, was left in very narrow circumstances. Jerome having obtained the ordinary school education, reading English, writing, and arithmetic, betook himself to the business of a pedlar. He began his philological pursuits with the study of the Hebrew and Greek tongues, and made himself so far master of these, without any assistance, as to be able to interpret the Hebrew Bible and Greek Testament into English *ad aperturam libri*. At this time he did not know one word of Latin. Some time afterwards, he was encouraged to prosecute his studies at the university of St Andrews; and an unexampled proficiency in every branch of literature recommended him to the esteem of the professors. Having finished his studies, he settled as schoolmaster at Dunkeld, where he died in 1757, in the 30th year of his age.

STONEHAVEN, or STONEHIVE, a seaport town in Kincardineshire, Scotland, occupies part of the parishes of Dunnotar and Fetteresso. It is situated in a south-westerly direction from Aberdeen, from which it is distant fifteen miles. The more ancient part of the town, which was built in the reign of Charles II., stands on the south side of the Carron, and presents an appearance somewhat paltry. But on the north side of the stream some elegant streets, with a square in the centre, have risen up under the auspices of Captain Barclay of Ury, upon whose ground they are built. Between the old and new towns there is a communication by means of a bridge. There is safe anchorage for shipping in the harbour, which is a natural basin, sheltered on the south-east by a high rock, and on the north-east by a quay, where goods can be landed with convenience and despatch. The harbour has been recently improved by the erection of a jetty. The vessels that sail out of this port are chiefly employed in the coal and lime trade, but the amount of tonnage is inconsiderable. Here many persons reside who occupy themselves in the herring-fishery; and there was formerly employment for a number of weavers, but their trade has in a great measure deserted them. The prosperity of the place depends in some degree upon the persons connected with the sheriff court of the county, which is held here. Although the capital of Kincardineshire, Stonehaven is only a borough of barony, of which the magis-

trates, who are authorized by the charter to preside in the justice of peace court, are appointed by the superior and feuars. A weekly market is held here, and also five annual fairs. In the vicinity of Stonehaven stand the parish churches of Dunnotar and Fetteresso. The town itself contains other two places of worship, one of which is an Episcopal chapel, and the other a meeting-house of the United Associated Synod. The population amounted in 1821 to 2150, and in 1831 to 2965.

STONES, in *Natural History*, have been defined bodies which are insipid, not ductile, nor inflammable, nor soluble in water. For a view of the classification of stones, and of their distribution, see MINERALOGY and GEOLOGY.

Some philosophers say that stones are vegetables; that they grow and increase in size like a plant. This theory, we believe, was first offered to the world by M. Tournefort, in the year 1702, after returning from his travels in the East. It was founded on a curious fact. In surveying the labyrinth of Crete, he observed that the names which visitors had engraved upon the rock were not formed of hollow, but of prominent letters, like basso-relievos. He supposes that these letters were at first hollowed out by knives; that the hollows have since been filled up by the growth of the stone; and hence he concludes that stones vegetate. We wish we were fully assured of the fact, that the letters were at first hollowed, before we attempt to account for their promineny. But even allowing the supposition to be true that they were at first hollow, we reply it is only a single fact, and that from a single fact it is altogether unphilosophical to deduce a general system. In the second place, this protuberancy of the characters is very improperly called vegetation, for it is not produced by a process in any respect like the vegetation of a plant. Vegetation supposes vessels containing fluids, and growth by expansion; but who ever heard of vessels in a stone, of fluids moving in them, or of the different parts expanding and swelling like the branch or trunk of a tree? Even the fact which Tournefort mentions proves nothing. He does not pretend to say that the rock itself is increasing, but only that a few small hollows are filled with new stony matter, which rises a little above the surrounding surface of the rock. This matter evidently has been once liquid, and at length has congealed in the channel into which it had run. But is not this easily explained by a common process, the formation of stalactites? When water charged with calcareous matter is exposed to the action of air, the water evaporates, and leaves the calcareous earth behind, which hardens and becomes like a stone.

Rocking STONE, or Logan, a stone of a prodigious size, so exactly poised that it would rock or shake with the smallest force. Of these stones the ancients give us some account. Pliny says, that at Harpasa, a town of Asia, there was a rock of such a wonderful nature, that if touched with the finger it would shake, but could not be moved from its place with the whole force of the body. Ptolemy mentions a gygonian stone near the ocean, which was agitated when struck by the stalk of an asphodel, but could not be removed by a great exertion of force. The word *gygonius* seems to be Celtic; for *gwingog* signifies *motitans*, the rocking stone.

Many rocking stones are to be found in different parts of this island; some natural, others artificial, or placed in their position by human art. In the parish of St Leven, Cornwall, there is a promontory called *Castle Treryn*. On the western side of the middle group, near the top, lies a very large stone, so evenly poised that any hand may move it from one side to another; yet it is so fixed on its base that no lever nor any mechanical force can remove it from its present situation. It is called the *Logan-stone*, and is at such a height from the ground that no person can believe that it was raised to its present position by art. But there

Stones.

Stone-
henge.

are other rocking stones, which are so shaped and so situated, that there can be no doubt but they were erected by human strength. Of this kind Borlase thinks the great *Quoit* or *Karn-lehau*, in the parish of Tywidnek, to be. It is thirty-nine feet in circumference, and four feet thick at a medium, and stands on a single pedestal. There is also a remarkable stone of the same kind in the island of St Agnes in Scilly. The under rock is ten feet six inches high, forty-seven feet round the middle, and touches the ground with no more than half its base. The upper rock rests on one point only, and is so nicely balanced that two or three men with a pole can move it. It is eight feet six inches high, and forty-seven in circumference. On the top there is a basin hollowed out, three feet eleven inches in diameter at a medium, but wider at the brim, and three feet deep. From the globular shape of this upper stone, it is highly probable that it was rounded by human art, and perhaps even placed on its pedestal by human strength. In Sithney parish, near Helston, in Cornwall, stood the famous logan or rocking stone, commonly called *Men Amber*, q. d. *Men an Bar*, or the *top-stone*. It was eleven feet by six, and four high, and so nicely poised on another stone that a little child could move it, and all travellers who came this way desired to see it. But Shruballs, Cromwell's governor of Pendennis, with much ado caused it to be undermined, to the great grief of the country. There are some marks of the tool on it, and, from its quadrangular shape, it was probably dedicated to Mercury.

That the rocking stones are monuments erected by the Druids, has by some writers been taken for granted; but tradition has not informed us for what purpose they were intended. Mr Toland thinks that the Druids made the people believe that they alone could move them, and that by a miracle; and that by this pretended miracle they condemned or acquitted the accused, and brought criminals to confess what could not otherwise be extorted from them. How far this conjecture is right, we shall leave to those who are deeply versed in the knowledge of antiquities to determine.

Sonorous STONE, a kind of stone remarkable for emitting an agreeable sound when struck, and much used in China for making musical instruments which they call *king*. The various kinds of sonorous stones known in China differ considerably from one another in beauty, and in the strength and duration of their tone; and what is very surprising is, that this difference cannot be discovered either by the different degrees of their hardness, weight, or fineness of grain, or by any other qualities which might be supposed to determine it. Some stones are found remarkably hard, which are very sonorous; and others exceedingly soft, which have an excellent tone; some extremely heavy emit a very sweet sound; and there are others as light as pumice-stone which have also an agreeable sound.

STONEHENGE, a celebrated monument of antiquity, stands in the middle of a flat area near the summit of a hill six miles distant from Salisbury. It is enclosed by a circular double bank and ditch near thirty feet broad, after crossing which we ascend thirty yards before we reach the work. The whole fabric consisted of two circles and two ovals. The outer circle is about 108 feet in diameter, consisting, when entire, of sixty stones, thirty uprights and thirty imposts, of which remain only twenty-four uprights, seventeen standing and seven down, three and a half feet asunder, and eight imposts. Eleven uprights have their five imposts on them by the grand entrance. These stones are from thirteen to twenty feet high. The smaller circle is somewhat more than eight feet from the inside of the outer one, and consisted of forty smaller stones (the highest six feet), of which only nineteen remain, and only eleven standing: the walk between these two circles is 300 feet in circumference. The adytum or cell is an oval formed of ten stones (from sixteen

to twenty-two feet high), in pairs, with imposts, which Dr Stukeley calls *trilithons*, and above thirty feet high, rising in height as they go round, and each pair separate, and not connected as the outer pair; the highest eight feet. Within these are nineteen smaller single stones, of which only six are standing. At the upper end of the adytum is the altar, a large slab of blue coarse marble, twenty inches thick, sixteen feet long, and four broad; pressed down by the weight of the vast stones that have fallen upon it. The whole number of stones, uprights, imposts, and altar, is exactly 140. The stones are far from being artificial, but were most probably brought from those called the *Gray Weathers*, on Marlborough Downs, fifteen or sixteen miles off; and if tried with a tool, they appear of the same hardness, grain, and colour, generally reddish. The heads of oxen, deer, and other beasts, have been found on digging in and about Stonehenge; and human bones in the circumjacent barrows. There are three entrances from the plain to this structure, the most considerable of which is from the north-east, and at each of them were raised on the outside of the trench two huge stones, with two smaller within, parallel to them.

It has been long a dispute among the learned, by what nation and for what purpose these enormous stones were collected and arranged. The first account of this structure we meet with is in Geoffrey of Monmouth, who, in the reign of King Stephen, wrote the history of the Britons in Latin. He tells us that it was erected by the counsel of Merlin the British enchanter, at the command of Aurelius Ambrosius, the last British king, in memory of 460 Britons who were murdered by Hengist the Saxon. The next account is that of Polydore Virgil, who says that the Britons erected this as a sepulchral monument of Aurelius Ambrosius. Others suppose it to have been a sepulchral monument of Boadicea, the famous British queen. Inigo Jones is of opinion that it was a Roman temple; from a stone sixteen feet long and four broad, placed in an exact position to the eastward, altar-fashion. Dr Charlton attributed it to the Danes, who were two years masters of Wiltshire. A tin tablet, on which were some unknown characters, supposed to be Punic, was digged up near it in the reign of Henry VIII., but is lost; probably that might have given some information respecting its founders. Its common name, *Stonehenge*, is Saxon, and signifies a "stone gallows," to which these stones, having transverse imposts, bear some resemblance. It is also called in Welch *choir gour*, or "the giants' dance."

Mr Grose thinks that Dr Stukeley has completely proved this structure to have been a British temple, in which the Druids officiated. He supposes it to have been the metropolitan temple of Great Britain, and translates the words *choir gour* "the great choir or temple." The learned Mr Bryant is of opinion that it was erected by a colony of Cuthites, probably before the time of the Druids; because it was usual with them to place one vast stone upon another for a religious memorial; and these they often placed so equably, that even a breath of wind would sometimes make them vibrate. Of such stones one remains at this day in the pile of Stonehenge. The ancients distinguished stones erected with a religious view by the name of *amber*; by which was signified any thing solar and divine. The Grecians called them *πετραὶ ἀμβροσίου*, *petræ ambrosiæ*. Stonehenge, according to Mr Bryant, is composed of these amber stones: hence the next town is denominated *Ambresbury*; not from a Roman Ambrosius, for no such person ever existed, but from the *Ambrosiæ petræ*, in whose vicinity it stood. Some of them were rocking stones; and there was a wonderful monument of this kind near Penzance in Cornwall, which still retains the name of *main-amber*, or the sacred stones. Such a one is mentioned by Apollonius Rhodius, supposed to have been raised in the time of the Argonautæ, in the island Tenos, as the monument of the

Stone-
henge.

Stoppers
||
Stove.

two winged sons of Boreas, slain by Hercules; and there are others in China and other countries.

STOPPERS, in a ship, certain short pieces of rope, which are usually knotted at one or both ends, according to the purpose for which they are designed.

STORNOWAY, a parish, seaport, and chief town in the island of Lewis, Scotland. The town is situated on a point of land at the head of Loch Stornoway, and was originally placed there by James VI. and erected by him into a borough of barony, in order to act as a means of civilization for the Western Islands. The harbour is capacious and of good depth, and the shipping belonging to the port is much more extensive than could be supposed for a place so remote and uninviting. The town consists of several streets of well-built slated houses, having numerous shops. Its public buildings are a neat and commodious custom-house, a town-house, a parish church, an assembly-room, and two school-houses. The town is a fishing station, and a large proportion of the inhabitants are therefore employed in the white and herring fisheries. The resident feuars and burgesses elect the town council and magistrates, consisting of two bailies and six councillors. The revenue of the borough is very small. The gross custom-house receipts collected here in 1838 amounted to L.519. 2s. 4d. The population of the parish in 1821 amounted to 4119, and in 1831 to 5422. The increase of the population is ascribed to the gradual improvement of the parish, but more particularly to the erection of new stations or villages for the purpose of improving the soil and prosecuting the fisheries.

STOURBRIDGE, a town in the hundred of Halfshire and county of Worcester, 123 miles from London. It stands on the river Stour, over which is a good stone bridge. By a canal it has communication with most parts of the kingdom, and thus distributes its productions, which consist of glass-ware, ironmongery, and pottery. From some excellent clay to be found in the vicinity, the inhabitants make a great number of crucibles. It is an ancient borough, governed by bailiffs and other officers, but sends no members to parliament. It has a market on Fridays. The inhabitants amounted in 1801 to 3431, in 1811 to 4072, in 1821 to 5090, and in 1831 to 6148.

STOURPORT, a market-town of the county of Worcester, which owes its origin to the recent formation of basins at the junction of the river Stour with the Severn. In these basins the barges that pass on the canals in the north of England meet the vessels which ascend the Severn from Bristol and Gloucester; and thus goods are transmitted from one part of the kingdom to the other with regularity and economy. The vicinity abounds in coal, much of which supplies the salt-makers at Droitwich, as well as the glass-makers in and around the place, and the iron-workers also, who abound in the neighbourhood. The town is well built, most of the houses being of recent erection. There is a handsome chapel of ease, and a magnificent iron bridge over the Severn, with a single arch of 150 feet span. On Wednesdays and Saturdays it has markets, which are well supplied. It is 124 miles from London, and eleven from Worcester. As it is a part of the parish of Old Swenford, which lies in two counties, the population-tables do not sufficiently show what has been the population of this new town at the four decennial parliamentary enumerations. It is now estimated at 6800.

STOVE, for heating apartments, green-houses, hot-houses, fruit-walls, &c.

When treating of the mechanical properties of air, we explained the manner in which the expansion occasioned by heat produces the draught up the chimney; and in the article **SMOKE** we considered the circumstances which tend to check, to promote, and to direct this current, so as to free us from the smoke and vitiated air which accompany the consumption of the fuel. Under **HEAT**, the communi-

cation and radiation have been fully explained. By the former, the caloric is given from one object to another, and communicated from particle to particle of the same object *by contact*; by the latter, it emanates in straight lines, through the air, from substance to substance, the emanations being absorbed by some bodies, and reflected by others.

The power which objects possess of receiving and communicating heat by the former of these modes, is termed their *conducting power*; by the latter, their *radiating*, their *absorbing*, and *reflecting* power. Those which receive it quickly by the former, also give it off quickly in the same way; and those which radiate powerfully also absorb powerfully; of course they reflect little: accordingly the radiating and reflecting powers are opposed to each other. Metals are good conductors; stones, bricks, and porous bodies of a similar nature, are bad conductors. The radiating, reflecting, and absorbing powers depend not so much on the nature of the substance, as on the surface. Highly polished surfaces radiate and absorb little, while dark and rough ones radiate and absorb powerfully; of course, resplendent surfaces are good reflectors.

When fuel is consumed with the view of heating apartments, the communication of heat depends entirely on the manner in which it is consumed. In an open fire-place or common grate, the heat thrown into the apartment is chiefly that emitted by radiation and reflection; the former coming directly from the fuel, and from the parts of the fire-place warmed by it; the latter being the radiated heat reflected by the polished parts of the grate. The rays thus thrown off, being absorbed by the objects in the room, then communicate warmth to the atmosphere which it contains. But part of the warmth must also be received by communication; for the walls adjoining the fire-place being heated by *contact*, will likewise communicate caloric to the air brought in contact with them; and as it is expanded it will ascend, and allow other particles to flow in, also to receive their supply. This however is small in comparison to that given to the apartment by radiation and reflection.

Much of the heat thus thrown into the room is carried off, indeed may be said to be lost; for, owing to the manner in which the fuel is consumed, a large supply of air is necessary for the combustion, which, rushing in upon the fuel, is itself, after acting on it, carried up the vent. Hence, to warm apartments in this way, a great deal of fuel is required. The quantity must depend very much on the form of the fire-place, and on the materials of which it is constructed.

The principle on which stoves operate is different. A stove, however modified in form, is merely a fire-place enclosed on all sides; the air necessary for the combustion entering from below, and carried off, as in a common grate, by a vent. Now, in this way of consuming fuel, the radiation is trifling in comparison to the communication by contact. Of course much must depend on the kind of stove employed; but it is allowed, that by far the greater part of the heat which the atmosphere of the room receives is that given directly by communication; for the air in contact with the sides of the stove is heated, is expanded, and carried upwards; and thus, by the constant flow of cool air on the stove, the whole of that in the room is warmed. No doubt, the stove being itself warm, must give off heat, not only by contact, but also by radiation; and the proportion thus emitted must depend on the temperature and surface, as already explained. But though heat is thus distributed, yet it must be borne in mind, that it is chiefly by contact that the atmosphere of the room is warmed; and as the air is thus easily heated, much less fuel is required than when it is burned in an open fire-place. The necessary supply of air is therefore not so great; and it is this which principally causes the difference in our feelings when in a room warm-

Stove.

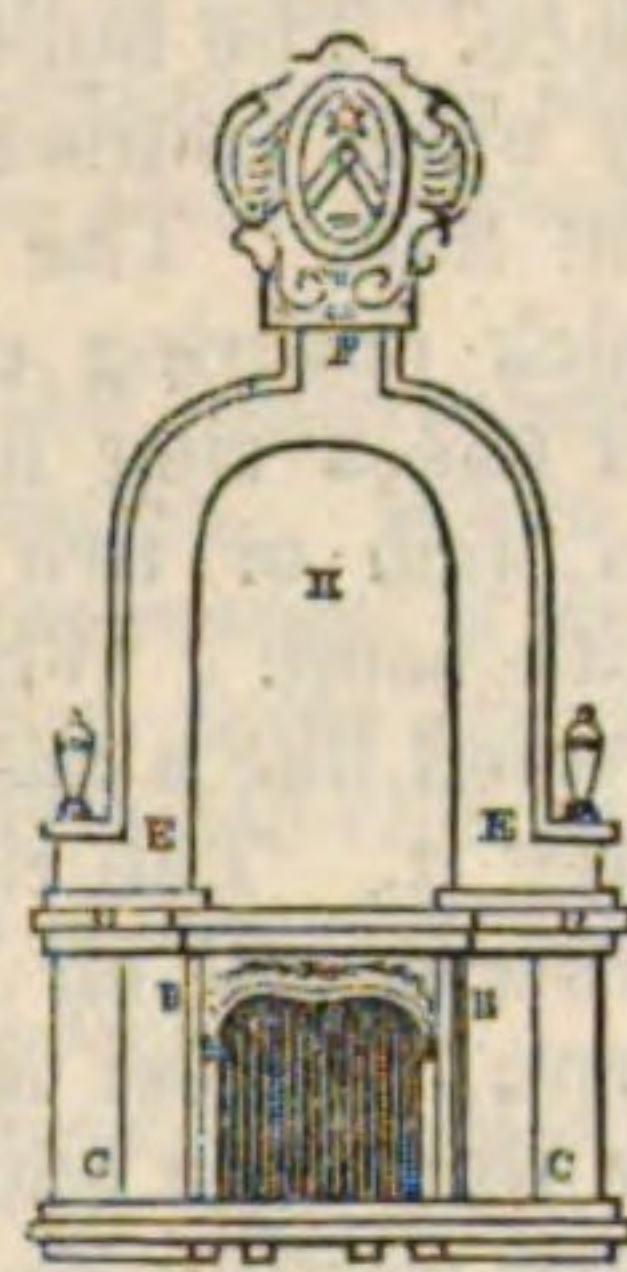
Stove. ed by a stove, and by a grate; for in the latter instance, not only have we the exhilarating influence excited by the blaze of the fuel, but there is a more rapid renewal of air through the apartment, and accordingly the atmosphere has not the close unpleasant feeling which it has when warmed by a stove.

The warming by stoves must therefore be conducted on principles different from those adopted in the employment of open fire-places. The general principle is, 1st, to employ the fuel in the most effectual manner for heating the external part of the stove, which is immediately efficient in warming the contiguous air, chiefly by contact; and, 2d, to keep within the room the air thus warmed, at least as much as is consistent with wholesomeness and cleanliness. It would occupy a volume to describe the immense variety of stoves which ingenuity has constructed. We shall content ourselves with giving a specimen of the two chief classes into which they may be distinguished.

The air of a room may be equally warmed by applying it either to the surface of a small stove made very hot, or to the surface of a much larger stove more moderately heated. The first kind is chiefly used in Holland, Flanders, and the milder climates of Germany and Poland. The last are used in the frozen climates of Russia and Sweden. The first are generally made of cast-iron, the last partly of iron and partly of brick-work.

Fig. 1 represents a small German stove, fully sufficient for warming a room of 24 feet by 18. The base is about three feet broad and fourteen inches deep, that is, from back to front, and six or seven feet high. The decoration is in the fashion of that country; but the operative structure of it will admit of any style of ornament. A is the fire-place, and the wood or charred coal is laid on the bottom, which has no bars. Bars would admit the air too freely among the fuel, and would both consume it too fast and raise too great a heat. That no heat may be uselessly expended, the sole of the fire-place and the whole bottom of the stove is raised an inch or two above the floor of the room, and the air is therefore warmed by it in succession, and rises upwards. For the same reason, the back of the stove is not in contact with the wall of the room, or of the niche in which it is placed. The fire-place is shut up by a door which fits closely to its case, and has a small wicket at the bottom, whose aperture is regulated by a sliding plate, so as to admit no more air than what suffices for slowly consuming the fuel. The flame and heated air rise to the top of the fire-place, three or four inches above the arch or mantle-piece, and get out laterally by two narrow passages B, B, immediately below the top-plate of the base. The current bends downward on each side, passes at C, C, under the partition-plates which divide the two side-chambers, and then rises upwards through the outer division of each, and passes through narrow slits D, D, in the top-plate, and from thence along the two hollow piers, E, E. The two lateral currents unite at the top of the arch, and go through the single passage F into the larger hollow behind the escutcheon G. From this place it either goes straight upwards into the vent in the wall by a pipe on the top of the stove, or it goes into the wall behind by a pipe inserted in the back of the stove. The propriety of this construction is very obvious. The current of hot air is applied to the exterior of the stove everywhere except in the two side-chambers of the base, where the partition-plates form one side of the canal. Even this might be avoided by making each of these side-chambers a detached hollow pillar. But this would greatly increase the trouble of construction and joining together, and is by no

Fig. 1.

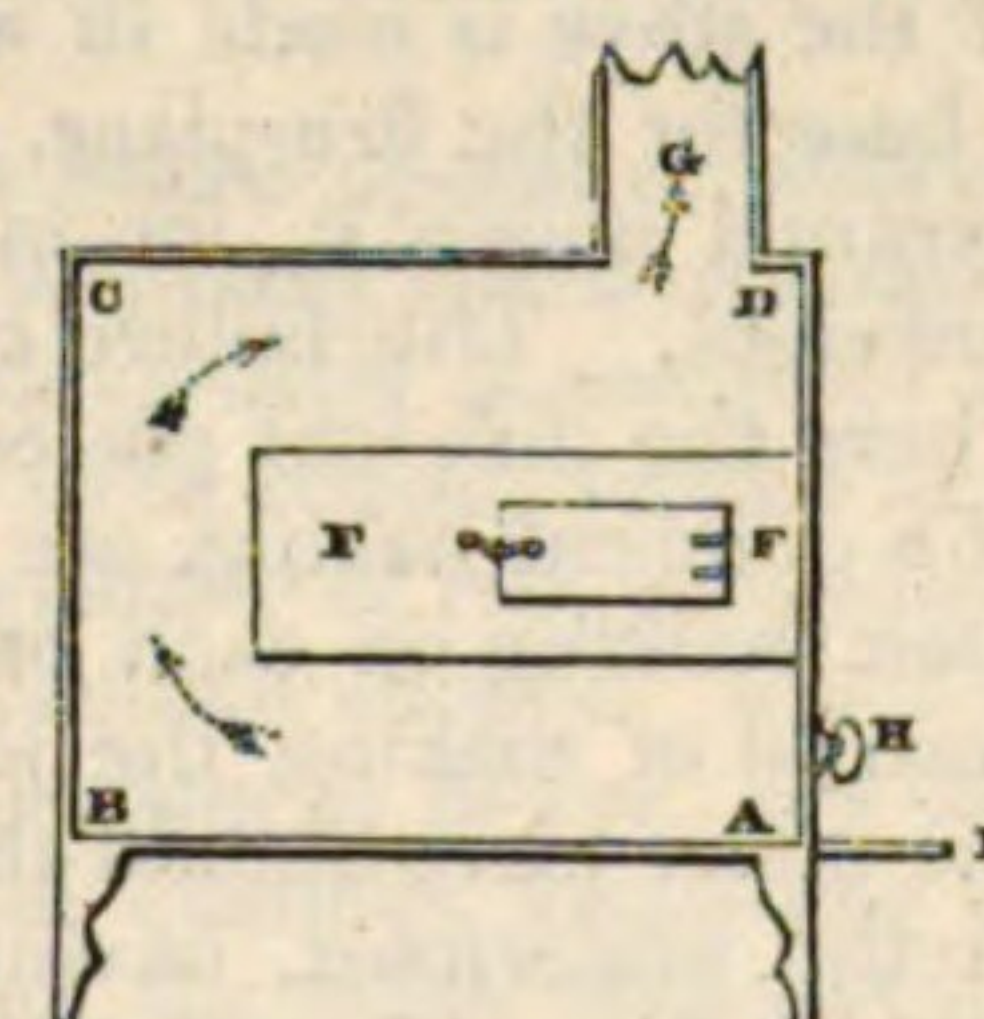


means necessary. The arch H has a graceful appearance, and affords a very warm situation for any thing that requires it, such as a drink in a sick person's bed-chamber, &c. Persons of a certain class use this place for keeping a dish warm; nay, the lower part of the arch is frequently occupied by an enclosed chamber, where the heat rises high enough even for dressing victuals, as will be easily imagined when we reflect that the sole of it is the roof of the fire-place.

The stove now described is supplied with fuel and with air by the front door opening into the room. That there may be space for fuel, this middle part projects a few inches before the two side-chambers. These last, with the whole upper part of the stove, are not more than ten inches deep. The passages therefore from the fire-place are towards the back of it; so that if we have a mind to see the fire, which is always cheerful, the door may be thrown open, and there is no danger of the smoke coming out after the current has once warmed the upper part of the stove. When the stove is of such dimensions that the base is about two feet and a half or three feet high, the fire-place may be furnished with a small grate in the British style. If the door is so hung that it can not only be thrown back, but lifted off its hinges, we have a stove-grate of the completest kind, fully adequate, in our mild climate, to warm a handsome apartment, even with an open fire; and when we hang on the door, and shut up the fire-place, a stove of the dimensions already given is almost too much for a large drawing-room.

A very simple form of stove is that represented in the annexed cut. It consists of a square box of iron, A B C D, resting on feet, and having a projecting hearth-plate at E. FF is an inner box projecting into the outer one. G is the chimney. The fuel is burned at A; and the flame passes to the chimney around the inner box, which may be used as an oven for cooking. At H there is a large door for the introduction of the fuel, in which there is also a smaller door. Both of these are generally kept shut when the furnace is in use; but when a greater heat is required, the smaller door is opened.

Fig. 2.



The effect of stoves as now described may be greatly increased, as is frequently done, by having the mouth communicating with or joined to an opening of the same dimensions, formed in the wall; and the door is in this case on the other side of the wall, in an antechamber or lobby. In some places the apartments are disposed round a spacious lobby, in which the doors of all the stoves are situated, and through which the fuel and air necessary for the combustion are supplied. But this method, though it warms the apartment, is very unfavourable to health and cheerfulness; for the same air confined and repeatedly breathed, and adulterated with the volatile emanations of the room, loses the refreshing quality which is so desirable, and even so necessary for health.

Something of this kind, it has been already mentioned, is unavoidable in all rooms warmed by stoves; and the hotter the surface of the stove, the more and more unpleasant does the air in it become; because, in addition to the slight renewal of air consequent on their use, when the surface becomes very hot, the impurities constantly floating in the atmosphere are decomposed, and emit offensive effluvia. The stove already described is almost always made of metal, and this objection applies particularly to it; hence the necessity of being attentive when cleaning it outside, to avoid the contact of greasy or oleaginous matter, which is so easily decomposed by heat, and gives off offensive and deleterious vapours.

Stove.

Stove.

The objections stated to the stoves as now described, have given rise to the use of those constructed of brick-work, or other materials of a similar nature. These are much used in Flanders, Holland, and Germany, where they are made of the most elegant forms, and finely decorated; but it is evident that they cannot be so effectual, nor equally warm a room with the same expense of fuel; earthen ware being inferior to metal in its conducting power. In addition to this, they are liable to a very great objection, the difficulty of preventing their cracking when heated; for different parts of the stove being of different heats, they expand unequally; and no cement can be expected to withstand this, especially when we recollect, that the heat which causes the baked earthen ware to expand, causes a contraction of the clay or cement with which the parts of the stove are joined together. Accordingly stoves of this kind do not stand long without cracking, even when strengthened by iron hoops and cramps judiciously disposed within them; nor does hooping them externally prevent it. When a crack is thus occasioned, it is not only unsightly, but may be dangerous, from its allowing the vitiated air to escape into the apartment.

For these and other reasons, we can scarcely hope to make stoves of brick-work or pottery which shall bear the necessary heat without cracking; and their use must therefore be confined to cases where very moderate heat is sufficient. We need not describe their construction. It is evident that it should be more simple than that of iron stoves; and we imagine, that in the very few cases in which they are likely to be employed in this country, a single fire-place, and an arch over it, divided by a partition or two of thin tile to lengthen the flue, will be quite enough. If the stove is made in whole or in part of potter's ware, a base for the fire-place, with an urn, column, obelisk, or pyramid above it, for increasing the surface, will also be sufficient. The failure commonly happens at the joinings, where the different pieces of a different heat, and perhaps of a different baking, are apt to expand unequally, and by their working on each other, one of them must give way. Instead of making the joints close and using any cement, the upper piece should therefore stand in a groove formed in the undermost, having a little powdered chalk or clay sprinkled over it, which will effectually prevent the passage of any air; and room being thus given for the unequal expansion, the joint remains entire. This may be considered as a general direction for all furnace-work, where it is in vain to attempt to hinder the mutual working of the parts. When fitted up with these precautions, the brick or pottery stoves are incomparably more sweet and pleasant than the iron ones.

But in the intense colds of Russia and Sweden, or even for very large rooms in this kingdom, stoves of these small dimensions are not sufficiently powerful; and we must follow the practice of those countries where they are made of great size, and very moderately heated. It is needless to describe their external form, which may be varied at pleasure. We shall only enlarge a little on the peculiarities connected with the general principle of their construction.

The stove is intended as a sort of magazine, in which a great quantity of heat may be quickly accumulated, to be afterwards slowly communicated to the apartment. The stove is therefore built extremely massive, and is found to be more powerful when coated with clay as wet as can be made to hang together. We imagine the reason of this to be, that very wet clay, and more particularly stucco, must become exceedingly porous when dry, and therefore a very slow conductor of heat. Instead of sticking on the glazed tiles with no more clay or stucco than is sufficient to attach them, each tile has at its back a sort of box, baked in one piece, about two or three inches deep. It is represented in fig. 3. This is filled with

mortar, and then stuck on the brick-work of the stove, which has a great number of iron pins or hooks driven into the joints, which may sink into this clay and keep it firmly attached when dry.

This coating, with the massive brick-work, forms a great mass of matter to be heated by the fuel. The lowest chamber, which is the fire-place, is somewhat wider, and considerably thicker than the stories

above, which are merely flues. When the fire-place is finished, and about to be arched over, a flat iron bar of small thickness is laid along the top of the side-wall on both sides, a set of finishing bricks being moulded on purpose, with a notch to receive the iron bar. Cross bars are laid over these, one at each end and one or two between, having a bit turned down at the ends, which takes hold of the longitudinal bars, and keeps them from being thrust outwards either by the pressure of the arch or by the swelling in consequence of the heat. In fig. 4, A is the cross section of one of the long bars, and BC is part of one of the cross bars, and CD is the clench which confines the bar A. This precaution is chiefly necessary, because the contraction of the stove upwards obliges the walls of the other stories to bear a little on the arch of the fire-place. The building above is kept together in like manner by other courses of iron bars at every second return of the flue. The top of the stove is finished by a pretty thick covering of brick-work. The last passage for the air has a ring lining its upper extremity, and projecting an inch or two above it. The flat round it is covered with sand. When we would stop this passage, a cover shaped like a basin or cover for dishes at table is whelmed over it. The rim of this, resting on the sand, effectually prevents all air from coming through and getting up the vent. Access is had to this damper by a door which can be shut tight enough to prevent the heated air of the room from wasting itself up the vent. When the room is too warm, it may be very rapidly cooled by opening this door. The warm air rushes up with great rapidity, and is replaced by cool air from without.

In a stove of this kind the fire is kindled early in the morning, after which the stove-door is shut, and the air-aperture below left open for some time to blow it up; but in the course of a short time, to prevent the too rapid consumption of the fuel, the fire-door is opened, by which the draught is checked. In this way the combustion is allowed to go on, and the materials of the stove become warmed, after which the air-passages are shut, so as to prevent any abstraction of heat by the current that would otherwise be occasioned. The stove thus becomes a great mass of heated matter, which is gradually pouring warmth into the apartment during the whole of the day; and as the temperature of the surface never becomes very high, the impurities in the atmosphere are not decomposed, and consequently it is free from those offensive effluvia unavoidable when metal stoves are used. One precaution, however, is necessary in the management of these stoves, which does not apply to the metal ones; we must take care that when the air-apertures are closed, there is no back-draught to carry the products of combustion into the apartment, which might be attended with fatal consequences. These being almost free from smoke, give little or no warning of their presence, and when inhaled for some time, produce giddiness and lassitude, and in some cases a dangerous state of insensibility. Hence the necessity of allowing the fire to be burned down, or nearly so, before closing the air-aper-

Stove.

Fig. 3.

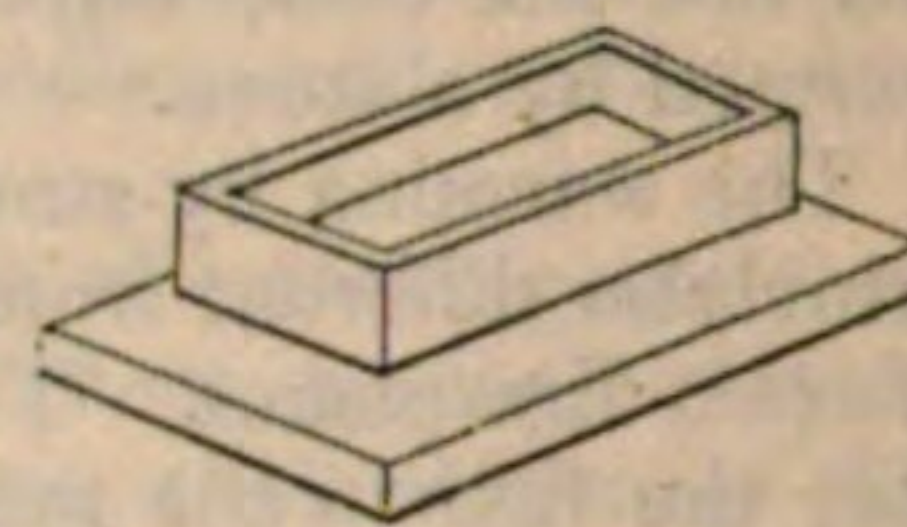
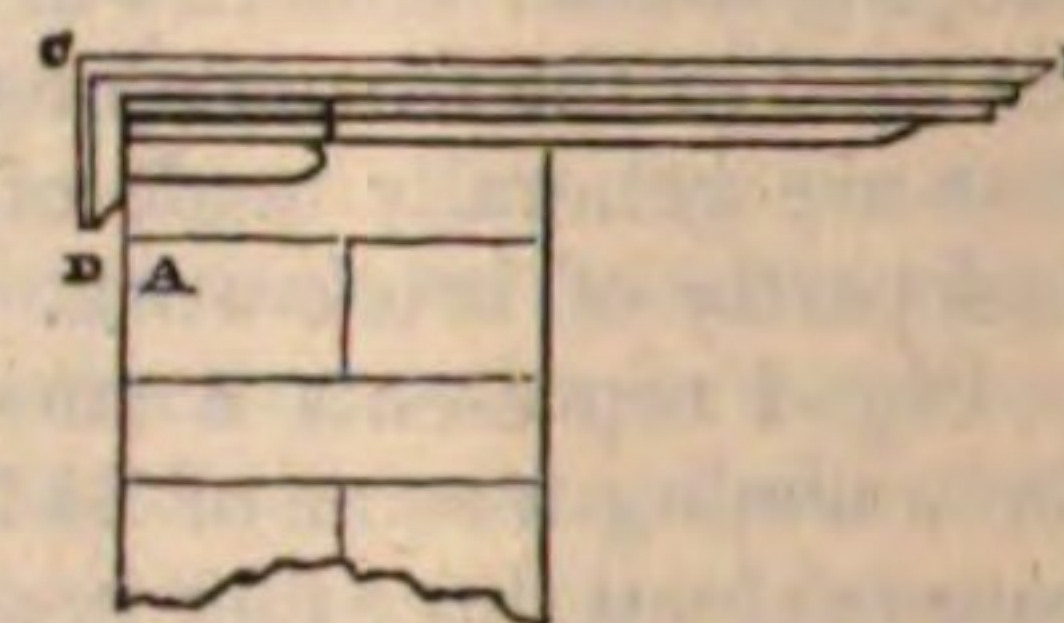


Fig. 4.



Stove. tures. Should the escape of the noxious gases into the room be suspected, the furnace-door and air-apertures must be opened, and a draught established through the stove, by kindling some wood shavings in it, the door and windows of the room being at the same time thrown open. This attention to back-draught is of course more necessary when charcoal or coke is used instead of coal, the products of combustion being then entirely free from smoke. When coal is used in stoves, the vent-tubes are apt to become choked with soot; but this may in a great measure be prevented by giving for a short time every day a brisk draught, by which the soot will be burned.

To prevent the injurious or disagreeable effects of the first kind of stoves, and at the same time to secure their advantages, numerous modifications have been proposed, not only with the view of preventing the too great heat of the external surface, but also of avoiding unnecessary expenditure of fuel. Perhaps the most important of these is *Arnott's stove*; the principle of which consists in allowing the fuel to burn very slowly, the admission of air for the combustion being regulated by an adjustment connected with the stove, and influenced by the degree of heat produced. Numerous forms and modifications of this stove are now in use, but in their general structure they are the same. The stove consists of a square or cylindrical box of iron, generally lined inside with a thick layer of fire-clay, and having a grating near the bottom, on which the fuel is burned; or the fuel may be contained in a small fire-box within the stove. Sometimes the fuel is burned within a hollow cylinder of fire-clay, in which case the stove is not lined with it. There is an ash-pit below for the reception of the ashes, and the products of the combustion are, as usual, carried off by a vent.

The principal feature of this stove is the contrivance by which the air is admitted for the combustion. When the stove-door or ash-pit door is open, the combustion is lively, and the fuel is soon consumed; but when these are shut, and they ought to be so made as to shut quite close, then air must be admitted otherwise, and this is done by the air-tube, furnished, as already stated, with a regulator.

The annexed figure represents the stove of its simplest form. ABCD is the outer casing of iron, in which there is the fire-box E, with its grating. Over the fire-box there is a dome, *k*, with a funnel to carry the products of combustion into the chimney; *h* is the stove-door, and *g* is the *thermometer regulator*, or adjustment by which the air is admitted for combustion. A great variety of these regulators has been described. Perhaps the best of these is represented by the annexed cut. ABC is a glass

Fig. 5.

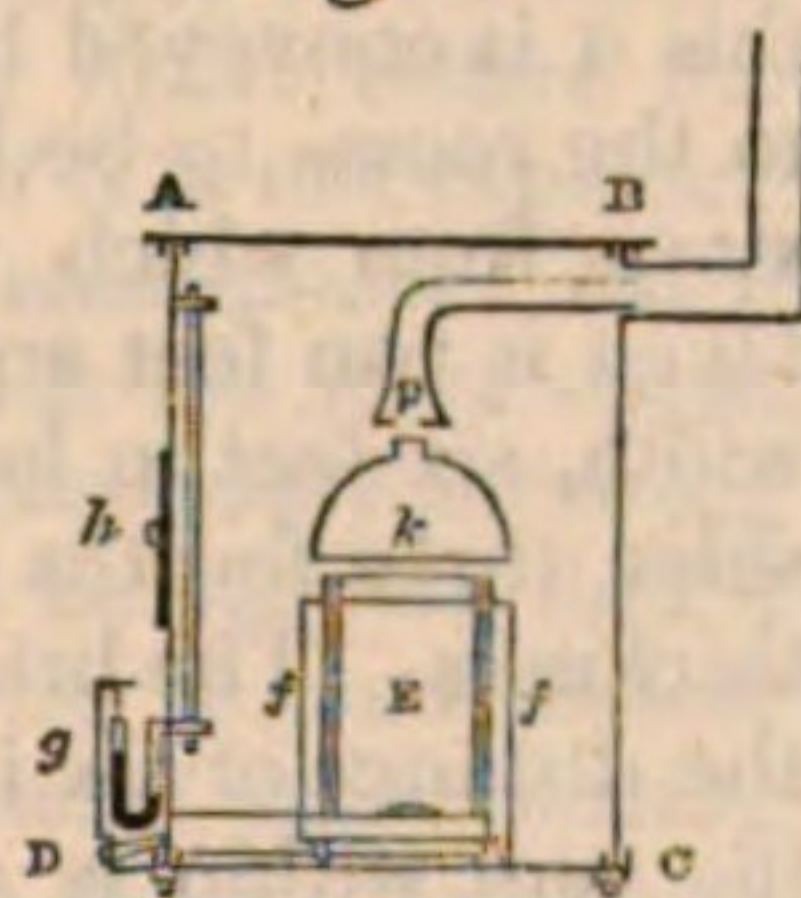
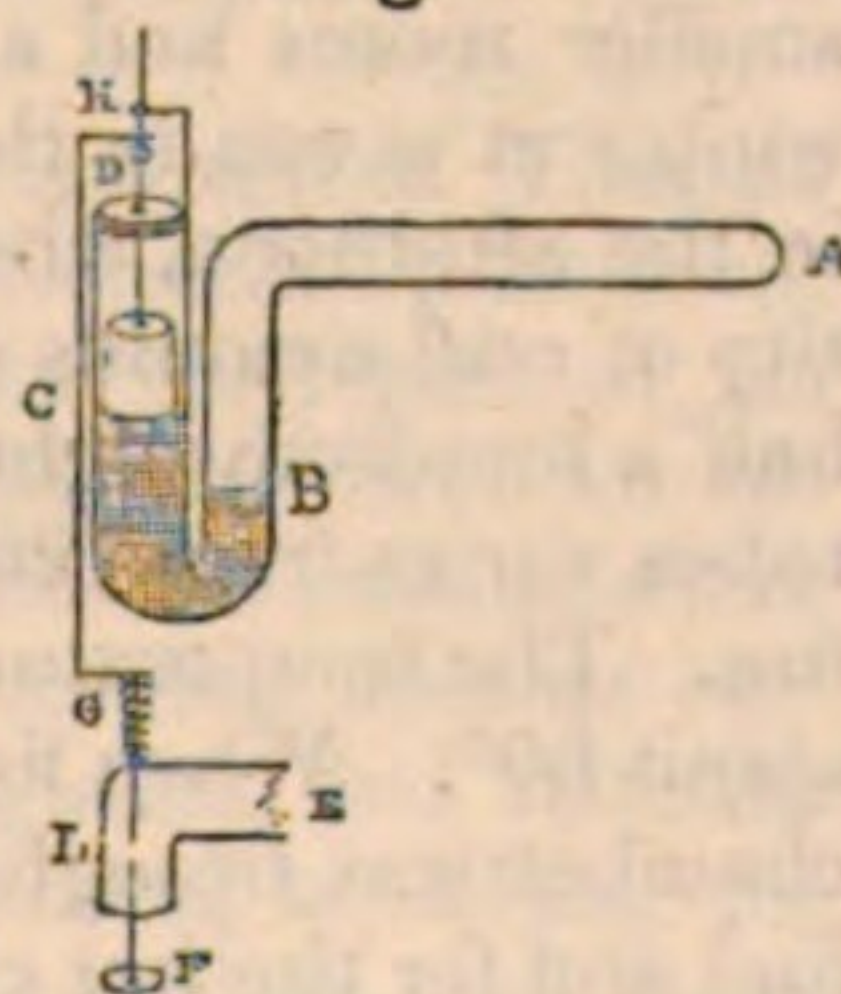


Fig. 6.



ABC is a glass tube, shut at A, containing air from A to B, and filled with mercury from B to C. On the mercury at C is placed a float, from which there proceeds an upright rod D, kept steady by passing through a support at H. From this upright wire there descends another, FGH, terminated by the plate-valve F. LE is the air-tube of the stove. When the heat within is great, the air in the shut limb of the regulator at A is expanded, and forces up the mercury at C, raising the rods and plate-valve F, and thus bringing it near to, or in contact with, the mouth of the tube, by which more or less air is admitted to the stove, according to the heat within. If the combustion is proceeding too slowly, then the air in the tube A is not much expanded, consequently air is allowed to enter the stove more

freely; but when, owing to this, the combustion becomes lively, and the temperature too high, then, by the elevation of the plate-valve, air enters in smaller quantity, and the temperature is moderated. Instead of the flat plate a conical valve is sometimes used, which, passing more or less into the mouth of the tube, allows the passage of less or more air; and sometimes this contrivance is resorted to. *ed* is the wire raised by the movement of the mercury; *ab* is a plate hung on an axis within the air-tube, and acting like a throttle-valve. When the edge of the plate is turned to the current, air is admitted freely; but when the heat becomes high, then the mercury rises and makes the plate revolve, by which more and more of the area of the tube is shut, and consequently less and less air is admitted. Perhaps the simplest of these regulators is that here represented. *abc* is a bent tube shut at *a*, where it contains air, and open at *c*, where it is cup-shaped. The bent part at *b* is occupied by mercury. From *c* there proceeds a bent tube to supply air to the stove. When the heat within is great, the air in *a* is expanded, and forces the mercury up in *c*, and thus, bringing it in contact with the mouth, prevents the free admission of air to the stove. Numerous other contrivances of a similar nature have been recommended, all acting in the same way. Instead of these, the admission of air is sometimes regulated by a semicircular slide over the mouth of the air-tube, which may be placed so as to admit to the stove a greater or smaller quantity, as occasion requires.

Fig. 7.

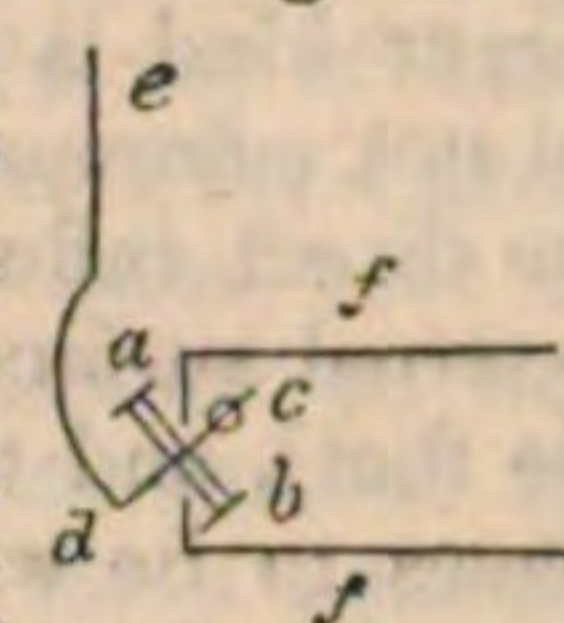
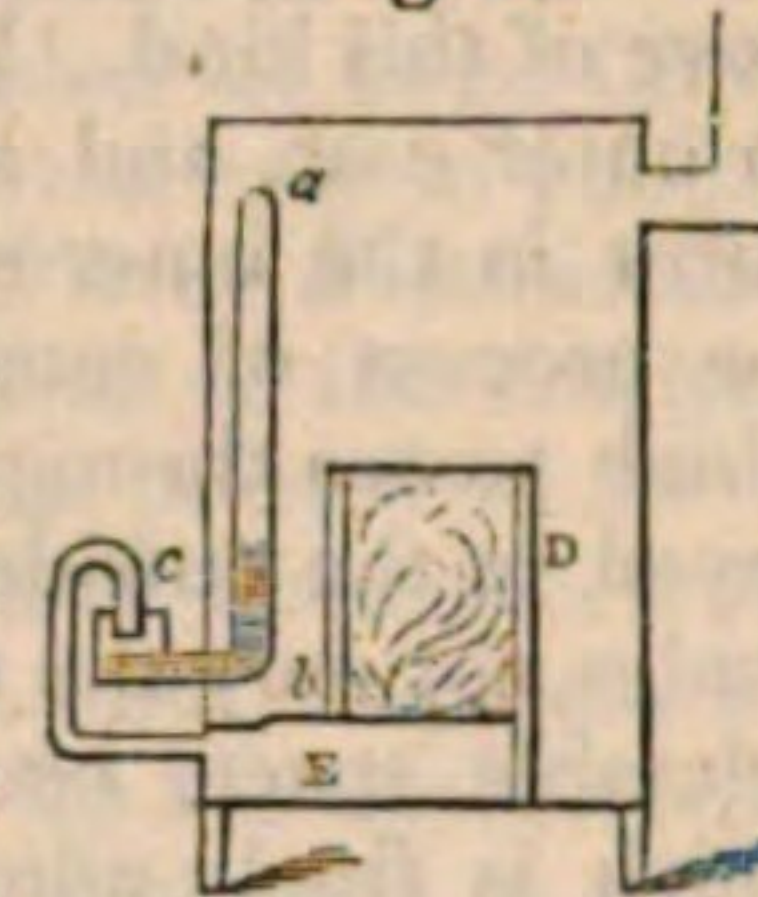


Fig. 8.



The principle on which this stove operates, whatever modification of it may be used, is merely the slow combustion of the fuel, by which the stove itself is warmed; and there is thus a reservoir of heat to be communicated to the air in the apartment. As the quantity of fuel consumed is small, there is no necessity for frequent supply. When one of the ordinary dimensions for a room is in use, it will require to be supplied morning and evening, supposing that it is kept constantly burning, and the ashes removed once a day. These, instead of falling into the ash-pit, may be received in a box placed there for the purpose, which is taken out and emptied, so as to avoid dust in the apartment.

The quantity of fuel consumed must of course depend on circumstances. During the severe winter of 1836-37, Dr Arnott kept his library at a temperature varying from 60° to 63° of Fahrenheit, by about six pounds of coal a day; which, supposing the coal to be twenty shillings per ton, is at the daily expense of less than a penny.

Though the Arnott stove answers well the purpose for which it is intended, that is, economy of fuel, for most undoubtedly a room may be kept warm at a very moderate expense, yet it is liable to the objection already stated with regard to the unpleasant feeling consequent on the use of all stoves of the kind, and indeed with it more than others; for, owing to the very slight expenditure of fuel, there is little or no change in the atmosphere. It is generally allowed that a pound of coal on an average requires about 150 cubic feet of air for combustion; but as part of the air passes off without being acted on, 200 may be allowed, and this is a large allowance where the combustion is going on so slowly as in the stove. Now suppose the apartment in which the stove is placed to be fifteen feet long by twelve wide and eleven in height, its cubic contents are 1980 feet; and suppose six pounds of coal per day to be the consumption, each pound requiring about 200, that is in all 1200 feet of air for combustion. This quantity must pass through the stove and be carried off by the vent, so

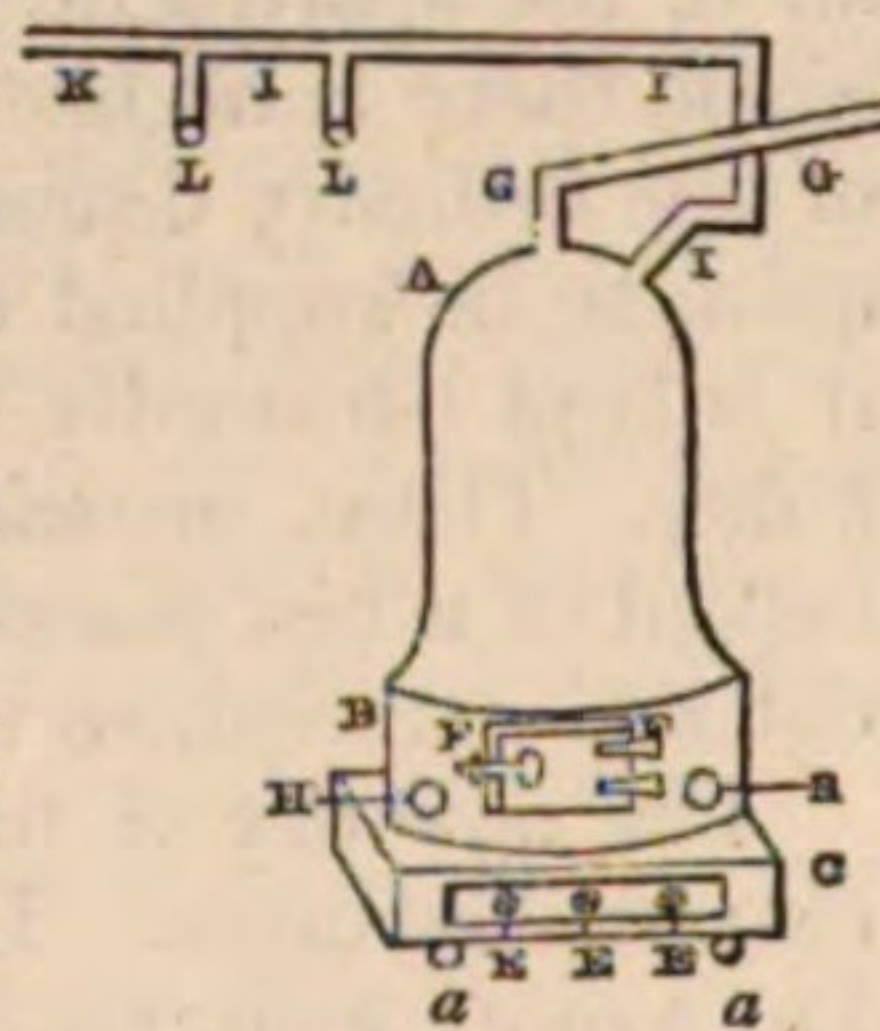
Stove. that in the course of twenty-four hours the atmosphere of the apartment is not once completely changed, and consequently renewed, by the direct influence of the fire. Hence it is that the apartment is so easily warmed; but it is this which necessarily renders it so unpleasant.

The stoves now described answer for small apartments. When the place to be heated is large, or when several apartments in the same building are to be warmed, a different kind is used. The heat in these cases is in general not communicated to the apartment or apartments by the direct influence of the stove, but by air heated by its external surface (of course not brought into contact with the fuel), and then conveyed by tubes or otherwise to the places to be warmed, on the principle already illustrated, that when heated it expands and ascends, and consequently rushes along the tubes, the supply being kept up by the constant flow of cold air upon the hot sides of the stove. Stoves for this purpose are made of iron or of brick-work, and sometimes of both. Fig. 9 represents a cast-metal stove of this kind. It may be considered as a double stove; an outer case, and a furnace or inner stove. The fuel is burnt in the inner stove, and the smoke produced during the process of combustion is carried off by a chimney, which passes through the top of the outer stove, and is conveyed to the outside of the building. The outer case includes not only the furnace or inner stove, but also a considerable space, occupied by the air of the atmosphere, which is freely admitted through a number of openings placed around it; and when any current of air is produced, it passes off from the space between the outer case and inner stove, and is conveyed by tubes through the body of the apartment. But we shall first describe the different parts of which the stove is composed, after which we shall be better able to understand its mode of operation.

Fig. 9 exhibits a perspective view of this stove. AB is the body, which is about three feet high, and of a circular form. C is a square pedestal, on which the stove is placed, and which contains the ash-pit. The height of the pedestal is about a foot, and it is nearly insulated by resting on the spherical supports *aa*, also of cast iron. EEE are openings in front of the ash-pit, through which the air enters to support the combustion. These openings can be enlarged or diminished, or opened and shut, at pleasure. FF is the door of the furnace, through which the fuel is introduced. This door is attached to the inner furnace, and is double. It is one foot broad, and eleven inches high. GG is the chimney, which passes from the furnace within, through the outer case, and conveys the smoke out of the building. HH are openings in the outer case, and are eight in number, through which the air enters, and being heated, is greatly rarefied, and passes off through the funnel or pipe III. This pipe communicates only with the outer stove, and being shut at the end K, the air rushes out from the small tubes LL, inserted into the side of the pipe III, and thus mixes with the cold air of the apartment. The diameter of the outer case at the bottom is about two feet, and the diameter of the furnace within is about sixteen inches.

The length of the body of a church in which two stoves of the form and dimensions now described are erected, is about sixty feet, and the breadth is about forty-five feet. The tubes III are conveyed along the lower edge of the gallery, about half the length of the church. The fires are lighted about four or five o'clock on the Sunday morning during the earlier part of the cold season, but as the season advances it is usual to light them earlier. From this time till the congregation assembles for the afternoon

Fig. 9.



service, the furnaces are constantly supplied with fuel. By this management the air in the church is kept comfortably warm during the coldest season of the year.

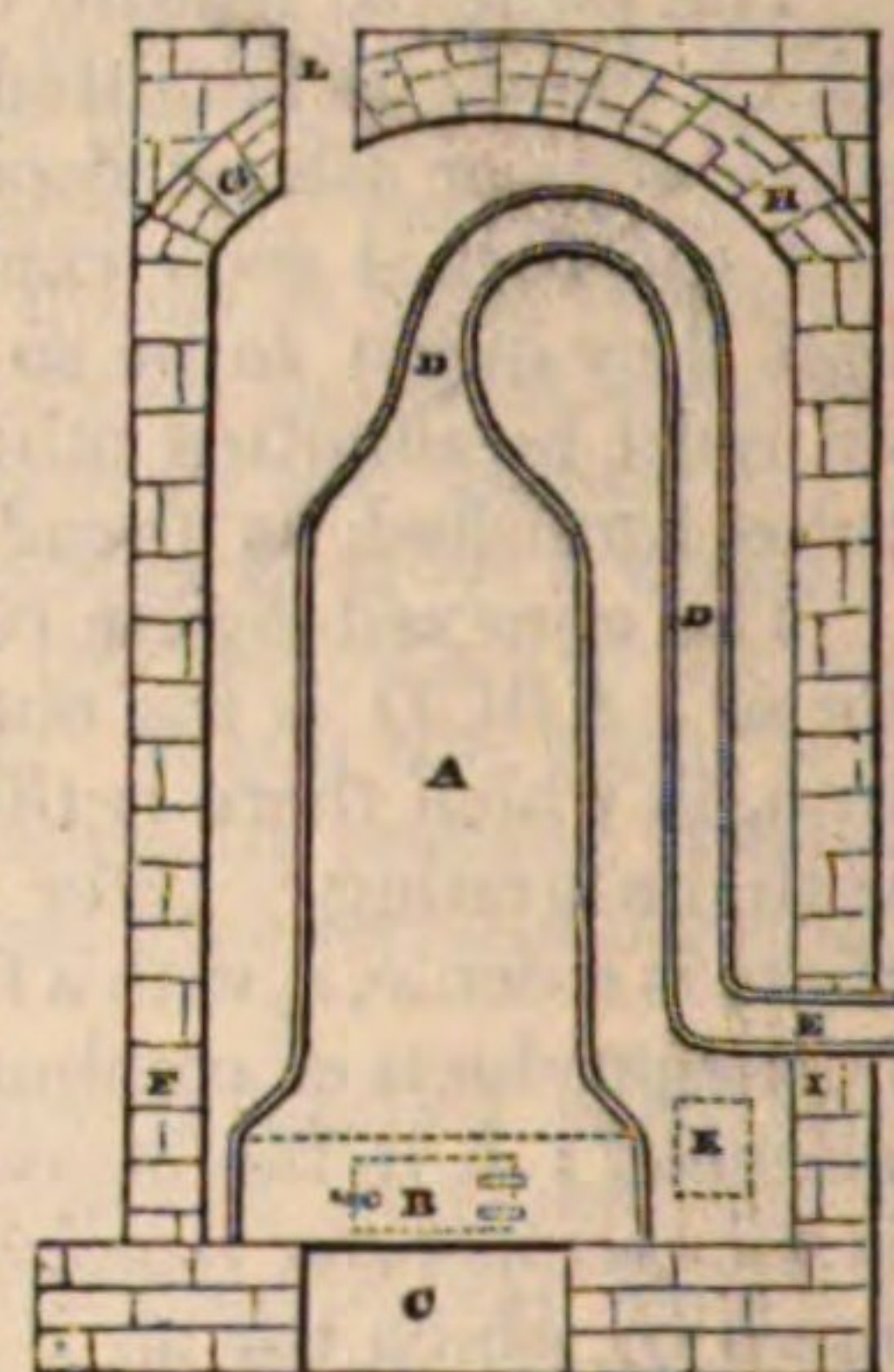
When only one apartment is to be heated by a stove of this kind, the stove ought to be placed in the apartment, because then it is supplied with air from it, which has been previously heated; whereas, when it is placed in another situation, the supply of heated air thrown into the apartment being derived from without, that within must be forced out to make way for it, and consequently at a great expenditure of fuel. When several apartments are to be warmed, suppose those of a dwelling-house, the stove ought to be situated in some part of the lobby, from which the tubes proceed to the rooms. Of course the size of the stove, and the distribution and size of the tubes, must depend on the supply of heat required.

There is one very great objection to the stove as now described. It has been already stated, that when air is projected against a red-hot surface, the impurities constantly floating in it are burned, and emit offensive effluvia; and this is generally the case with metallic hot-air stoves. Hence the necessity of having them so placed that they shall be supplied with air as free as possible from impurities. Instead of having the whole of the stove made of metal, the inner part is sometimes metal and the outer covering brick-work; in which case the chamber between them is generally larger than in the others, consequently the temperature does not become so high, and the objection urged against the metal stoves is in a great measure removed.

The annexed figure represents a vertical section of a stove of this kind. A is the stove of metal, with the door at B and ash-pit at C. DD is the vent, making a turn downwards, and carried into the chimney at E. FGHI is the outer casing of brick-work, completely enclosing the stove, and also the descending part of the vent; K is the opening for the admission of air to the hot chamber. L is the tube for carrying off the warm air, and from this it is conveyed by other tubes to the rooms to be heated. The stove from which this figure is taken is two feet and a quarter in width, six feet in height, and the sides three fourths of an inch in thickness. The brick casing is at the distance of six inches from the metal, and the descending vent within is six inches in diameter. It is used for warming a lecture-room thirty-five feet long, twenty-seven broad, and twenty high, also a large apartment thirty feet long, twenty-seven broad, and eighteen high, besides two smaller rooms and a staircase. The fire is kindled during winter at seven in the morning, and kept burning till four in the afternoon, when it is allowed to go out. The quantity of coal amounts daily, on an average, to rather less than half a hundredweight. The temperature of the air from the tubes varies from 120° to 180°, according to the state of the fire. The temperature of the different apartments is kept at about 60°. When first erected, the supply of air for the hot chamber was brought from without; but now the air for the fuel and for the hot chamber are both taken from the apartment in which the stove is placed, which is generally at the temperature of 70°.

When the place to be heated is spacious, or when there are several apartments, it is customary to have the part of the stove immediately exposed to the fire lined with fire-brick, in order to prevent the direct action of the fuel on

Fig. 10.



Stow. the metal; for in these instances the stove is much larger than that described, and consequently the fire more powerful. Its size must depend on the size and number of the apartments. In its general construction it resembles the other, consisting of the inner part for the fuel, with its grating, ash-pit, and vent, and of the outer casing, with the aperture for the supply of air to the chamber, and the tube or tubes for its transmission to the apartments.

The great advantage attending the use of stoves of this kind is, that they do not become so warm as to decompose the impurities in the air flowing into the hot chamber, and consequently there are no offensive effluvia generated. As the temperature is not so high as that of metal stoves, more of the warm air is requisite, by which there is a frequent renewal of that in the apartment, and the temperature throughout is more uniform than when a smaller quantity of hotter air is admitted. It has already been mentioned that the temperature of the air from the hot chamber of the stove described is from 120° to 180°. Perhaps this is higher than it ought to be. Many prefer having the stove so constructed that the temperature of the air which it throws into the apartment shall not exceed 70°. Of course, in this case, a much larger quantity of it is necessary. By throwing in a sufficient supply, that of the apartments may be maintained at about 60°. The mouths of the hot air-tubes are made to terminate as near the floor as possible, that the air may rise, and gradually mix with the atmosphere of the apartment.

In erecting stoves for the supply of hot air in this way, there are many circumstances to be considered, to which it would here be useless to allude. Much must depend on local situation, the size and number of the apartments, and the draught through them. These considerations must be left to the skill and ingenuity of the workman, who must be guided by keeping in view the general principles which determine the supply of air to the furnace, the ascensional force of the column of warm air to be conveyed through the tubes, the manner in which the apartments to be warmed are disposed, &c.

In heating buildings by these stoves when they are not in constant use, as is the case in churches, the time for keeping them going must also depend on circumstances. If the object is merely to throw in a supply of warm air, then the stove must be kindled a few hours before the apartment is to be occupied, especially if it is not expected that there shall be much change in its atmosphere; but if the object is to keep the place warm, then the stove ought to be kept in constant use, so as to be constantly throwing in warm air. During night the fire can be damped, and it is again made brisk when required. This is much better than allowing the fire to go out, because in again heating the stove to the requisite temperature, there must be a considerable waste of fuel. After the fire is in good condition, and the stove well heated, the combustion should be allowed to proceed slowly, which is accomplished by the proper regulation of the draught. (D. H.)

STOW, JOHN, an industrious historian, son of Thomas Stow, merchant-tailor, of St Michael's, Cornhill, in London, was born about the year 1525. Of the early part of his life we know very little, except that he was bred to his father's business, which in the year 1560 he relinquished, devoting himself entirely to the study of our ancient historians, chronicles, annals, charters, registers, and records. Of these he made a considerable collection, travelling for that purpose to different parts of the kingdom, and transcribing such manuscripts as he could not purchase. But this profession of an antiquary being attended with no present emolument, he was obliged for subsistence to return to his trade. It happened, however, that his talents and necessities were made known to Dr Parker, archbishop of Canterbury; who being himself an antiquary, encouraged

and enabled Stow to prosecute his darling study. In those times of persecution, though Elizabeth was then upon the throne, honest John Stow did not escape danger. His collection of popish records was deemed a cause of suspicion. His younger brother Thomas preferred no less than 140 articles against him before the ecclesiastical commission; but the proof being insufficient, he was acquitted. In 1565 he first published his Summary of the Chronicles of England. About the year 1584 he began his Survey of London. In 1585 he was one of the two collectors for a great muster of Limestreet ward. During the same year he petitioned the corporation of London to bestow on him the benefit of two freemen, to enable him to publish his Survey; and in 1589 he again petitioned for a pension. Whether he succeeded is not known. He was principally concerned in the second edition of Holinshed's Chronicle, published in 1587. He also corrected and twice augmented Chaucer's Works, published in 1561 and in 1597. His Survey of London was first published in 1598. To these laborious works he would have added his large Chronicle, or History of England; but he lived only to publish an abstract of it, under the title of "*Flores Historiarum*, or Annals of this Kingdom, from the time of the Ancient Britons to his own." This work was printed in 1600. The folio volume which was printed after his death, with the title of Stow's Chronicle, was taken from his papers by Edmund Howes. Having thus spent his life and fortune in these laborious pursuits, he was at last obliged to solicit the charitable and well-disposed for relief. For this purpose, King James I. granted him in 1603 a brief, which was renewed in 1604, authorizing him to collect in churches the benefactions of his fellow-citizens. He died in April 1605, aged eighty; and was buried in his parish church of St Andrew's Undershaft, where his widow erected a decent monument to his memory. John Stow was a most indefatigable antiquary, a faithful historian, and an honest man.

STOW ON THE WOLD, a town of the hundred of Haughton, in the county of Gloucester, eighty-two miles from London. It stands on a hill in a wild district near the river Windrash. It is irregularly and not well built. The parish is very extensive, though not densely peopled. The town has a market on Thursday, and several fairs at which sales are made of hops, sheep, and cheese. The inhabitants amounted in 1801 to 1471, in 1811 to 1544, in 1821 to 1731, and in 1831 to 1810.

STOWEY-NETHER, a town of the county of Somerset, in the hundred of Willerton and Freemanners, six miles from Bridgewater, and 149 miles from London. It is in a fertile district at the foot of the Quanloch Hills. It formerly contained a castle, of which no vestige now appears, though the ditch that surrounded it may be traced. The parish church is a handsome building; and near to it is a spring, which has the property of incrusting, with the appearance of stone, pieces of wood, or other substances that may be thrown into it. There is a small market held on Thursday. The population amounted in 1801 to 586, in 1811 to 620, in 1821 to 773, and in 1831 to 778.

STOWMARKET, a town in the hundred of Stow and county of Suffolk, seventy-six miles from London. It stands on the river Orwell, and has also a canal. It is a place of small trade, with a market on Thursday. The inhabitants amounted in 1801 to 1761, in 1811 to 2006, in 1821 to 2252, and in 1831 to 2672.

STOWAGE, the general disposition of the several materials contained in a ship's hold, with regard to their figure, magnitude, or solidity.

STRABO, an illustrious geographer, was born at Amasia, a city of Cappadocia. The time of his birth cannot be ascertained, but he is known to have flourished during the age of Augustus and Tiberius. He studied under

Stow on
the Wold
||
Strabo.

Strada.

Xenarchus, a Peripatetic philosopher; but afterwards, influenced by the authority of Athenodorus, who had been his preceptor, and who became eminent in the reign of Augustus, he adopted the tenets of the Stoics. He obtained the friendship of Cornelius Gallus, governor of Egypt. In order to collect materials for his great work, he travelled in many different regions; and after much toil and research completed his Geography, which is justly regarded as a very precious relique of antiquity. It consists of seventeen books, all of which are not however entire. The first two books are employed in showing that the study of geography is not only worthy of, but even necessary to, a philosopher; the third describes Spain; the fourth, Gaul and the Britannic isles; the fifth and sixth, Italy and the adjacent isles; the seventh, which is imperfect at the end, Germany, the countries of the Getæ and Illyrii, Taurica Chersonesus, and Epirus; the eighth, ninth, and tenth, Greece with the neighbouring isles; the four following, Asia within Mount Taurus; the fifteenth and sixteenth, Asia without Taurus, India, Persia, Syria, Arabia; and the seventeenth, Egypt, Ethiopia, Carthage, and other countries of Africa.

Strabo's Geography first appeared in a Latin version, executed by Phavorinus and Tifernas, and printed at Rome by Sweynheym and Pannartz. It is an ample folio volume, without date, but is supposed to have been printed in or about the year 1469. The earliest edition with a date is that of Venice, 1472, fol. The *editio princeps* of the Greek text proceeded from the press of Aldus, Venet. 1516, folio. This edition, which is not distinguished by its accuracy, was succeeded by that of Marcus Hopper, Basil. 1549, fol. He has printed a Latin translation by Glareanus and Hartungus. An edition, containing an elegant version, with notes and castigations, was next produced by Xylander, Basil. 1571, fol. But all these were eclipsed by the edition of Casaubon, Genev. 1597, fol. By the aid of four MSS. and of his own critical sagacity, he greatly improved the Greek text. He retained the version of Xylander. He afterwards augmented and improved his annotations, and the work was reprinted at Paris in 1620, after the death of the very learned editor. This second edition of Casaubon, together with the notes of various other critics, was republished by T. Janson van Almeloveen, Amst. 1707, fol. He has subjoined the *Chrestomathia*, or epitome of Strabo; which, according to Dodwell, was compiled by some unknown writer between the years 976 and 996. It had been found of some use, not only in contributing to the correction of the text, but likewise in supplying to a certain extent the defect of the seventh book. An elaborate and valuable edition of Strabo was commenced by Siebenkees, and completed by Tzschucke, Lipsiæ, 1796-1819, 7 tom. 8vo. Much was expected from the edition of Falconer, Oxon. 1807, 2 tom. fol. It was one defect of the editor, that he was not sufficiently acquainted with the labours of the continental critics. Nor must we overlook an edition of the text, illustrated with Greek notes by Coray, Paris. 1815, 4 tom. 8vo. Strabo was translated into German by Penzel. A French translation was undertaken by command of the emperor, and was executed by De la Porte du Theil, Coray, and Letronne. The introduction, and the notes distinguished by the letter G, were contributed by Gossellin. "Géographie de Strabon, traduite du Grec en Français." Paris, 1805-19, 5 tom. 4to.

STRADA, FAMILIANUS, an ingenious and learned Jesuit, was born at Rome in the year 1572, and there taught rhetoric for fifteen years. He wrote several pieces upon the art of oratory, and published some orations with a view of illustrating by example what he had inculcated by precept. But his "Prolusiones Academicæ" and his "Historia de Bello Belgico" are the works which raised his re-

putation, and have preserved his memory. His history of the war of Flanders was published at Rome, the first deced in 1640, the second in 1647; the whole extending from the death of Charles V. which happened in 1558, to the year 1590. It is written in good Latin, as all allow; but its merit in other respects has been variously estimated. His "Prolusiones Academicæ" show great ingenuity, and a masterly skill in classical literature; that prolusion especially in which he introduces Lucan, Lucretius, Claudian, Ovid, Statius, and Virgil, each of them versifying according to his own strain. This work has often been printed. Strada died at Rome in the Jesuits College in the year 1649.

STRAHAN, WILLIAM, an eminent printer, was born at Edinburgh in the year 1715. His father, who had a small appointment in the customs, gave his son the education which every one of decent rank then received in a country where the avenues to learning were easy, and open to men of the most moderate circumstances. After having passed through the tuition of a grammar-school, he served an apprenticeship to a printer, and when a very young man removed to a wider sphere in that line of business, and went to follow his trade in London. Sober, diligent, and attentive, while his emoluments were for some time very scanty, he contrived to live rather within than beyond his income; and though he married early, and without such a provision as prudence might have looked for in the establishment of a family, he continued to thrive, and to better his circumstances. This he would often mention as an encouragement to early matrimony; and used to say, he never had a child born that Providence did not send some increase of income to provide for the increase of his household. With sufficient vigour of mind, he had that happy flow of animal spirits that is not easily discouraged by unpromising appearances.

His abilities in his profession, accompanied with perfect integrity and unabating diligence, enabled him, after the first difficulties were overcome, to advance with rapid success. And he was one of the most flourishing men of the trade, when, in the year 1740, he purchased a share of the patent for king's printer, of Mr Eyre, with whom he maintained the most cordial intimacy during the rest of his life. Beside the emoluments arising from this appointment, as well as from a very extensive private business, he now drew largely from a field which it required some degree of speculative sagacity to cultivate, on account of the great literary property which he acquired by purchasing the copyrights of the most celebrated authors of the time. Here his liberality kept pace with his prudence, and in some cases went perhaps rather beyond it. Never had such rewards been given to the labours of literary men, as were received from him and his associates in their purchases of copyrights.

Having now attained the first great object of business, wealth, Mr Strahan looked with a very allowable ambition on the stations of political rank and eminence. Politics had long occupied his active mind, and he had for many years pursued them as his favourite amusement, by corresponding on that subject with some of the first characters of the age. Mr Strahan's queries to Dr Franklin in the year 1769, respecting the discontents of the Americans, published in the London Chronicle of 28th July 1778, show the just conception which he entertained of the important consequences of that dispute, and his anxiety as a good subject to investigate, at that early period, the proper means by which their grievances might be removed, and a permanent harmony restored between the two countries. In the year 1775 he was elected a member of parliament for the borough of Malmesbury in Wiltshire, with a very illustrious colleague, Mr Fox; and in the succeeding parliament, for Wootton Bassett, in the same county. In this station, applying himself

Strahan.

Straiks
||
Strait.

with that industry which was natural to him, he was a useful member, and attended the house with a scrupulous punctuality. His talents for business acquired the consideration to which they were entitled, and were not unnoticed by the minister.

In his political connection, he was constant to the friends to whom he had first been attached. He was a steady supporter of that party who were turned out of administration in spring 1784, and lost his seat in the House of Commons by the dissolution of parliament with which that change was followed; nor did he show any disposition to resume his place on the return of the new parliament. He had begun to feel some decline in his health, which had rather suffered from the long sittings with which the political warfare had been attended. Without any fixed disease, his strength visibly decayed; and though his spirits survived his strength, yet the vigour and activity of his mind were considerably impaired. Both continued gradually to decline till his death, which happened on the 9th of July 1785, in the seventy-first year of his age.

STRAIKS, in the military art, are strong plates of iron, six in number, fixed with large nails called *straih-nails*, on the circumference of a cannon-wheel, over the joints of the fellows, both to strengthen the wheel, and to save the fellows from wearing on hard ways or streets.

STRAIN or STRESS, in *Mechanics*, are terms indiscriminately used to express the force which is excited in any part of a machine or structure of any kind, tending to break it in that part. Thus every part of a rope is equally strained by the weight which it suspends. Every part of a pillar is equally strained by the load which it supports. A mill axle is equally twisted and strained in every part which lies between the part of the wheel actuated by the moving power and the part which is resisted by the work to be performed. Every part of a lever or joist is differently strained by a force acting on a distant part.

It is evident that we cannot make the structure fit for its purpose, unless the strength at every part be at least equal to the stress laid on, or the strain excited in that part. It is no less plain, that if we are ignorant of the principles which determine this strain, both in intensity and direction, in relation to the magnitude and the situation of its remote cause, the only security we have for success is to give to every part of the assemblage such solidity that we can leave no doubt of its sufficiency. But daily experience shows us that this vague security is in many cases uncertain, if we are thus ignorant. In all cases it is slovenly, unlike an artist, attended with useless expense, and in machines is attended with a loss of power which is wasted in changing the motions of a needless load of matter.

It must therefore greatly tend to the improvement of all professions occupied in the erection or employment of such structures, to have a distinct notion of the strains to which these parts are exposed. Frequently, nay generally, these strains are not immediate, but arise from the action of forces on distant parts, by which the assemblage is strained, and there is a tendency to rupture in every part. This strain is *induced* on every part, and is there modified by fixed mechanical laws. These it is our business to learn; but our chief object in this investigation is to determine the strength of materials which it is necessary to oppose in every part to this strain, and how to oppose this strength in such a manner that it shall be exerted to the best advantage. The notions of strain and strength therefore hardly admit of separation; for it is even by means of the strength of the intermediate parts that the strain is propagated to, or excited in, the part under consideration. It is proper therefore to consider the whole together under the article **STRENGTH OF MATERIALS.**

STRAIT, a narrow channel or arm of the sea, enclosed between lands on either side, and affording a passage out of one great sea into another.

VOL. XX.

There are three kinds of straits. 1. Such as join one ocean to another. Of this kind are the Straits of Magellan and Le Maire. 2. Those which join the ocean to a gulf: the Straits of Gibraltar and Babelmandel are of this kind, the Mediterranean and Red Sea being only large gulfs. 3. Those which join one gulf to another; as the Straits of Caffa, which join the Palus Mæotis to the Euxine or Black Sea.

STRAKES, or STREAKS, in a ship, the uniform ranges of planks on the bottom and sides of a ship, or the continuation of planks joined to the ends of each other, and reaching from the stem to the stern-post and fashion-pieces; the lowest of these, which is called the *garboard streak*, is let into the keel below, and into the stem and stern-post. They say also a ship *heels a strake*, that is, hangs or inclines to one side, the quantity of a whole plank's breadth.

STRAKES, or *Streks*, in mining, are frames of boards fixed on or in the ground, where they wash and dress the small ore in a little stream of water, hence called *straked ore*.

STRALSUND, one of the governments into which the Prussian province of Pomerania is divided. It comprehends the whole of what was Swedish Pomerania, with the island of Rugen, and some others in the Baltic Sea. It extends over 1584 square miles, and contains fourteen cities and towns, and 347 villages. The population, by the census of 1817, amounted to 129,239, and by that of 1834 to 153,945. With the exception of about 450 Catholics and 152 Jews, all the inhabitants are of the Lutheran church. The soil is generally fertile and well cultivated, yielding of corn, flax, and hemp, more than is consumed. The capital, a city of the same name, stands in the island of Rugen, opposite the Strait of Gellen, by which it is separated from the continent. The harbour is good and secure, and the city is strongly fortified both on the land and the sea sides. It is ancient, and in a style of building corresponding to its age. It has five churches and a college, with a few other public buildings. In the year 1834 it contained 14,713 inhabitants, who have extensive foreign trade, chiefly in domestic productions. Long. 13. 29. E. Lat. 54. 6. N.

STRANGE, SIR ROBERT, an eminent engraver, who carried the art to great perfection in this country, and was distinguished not only as an artist, but highly respected and beloved on account of his private virtues and domestic habits. Modest as he was ingenious, he used to say that the works of an artist should serve for his life and monument. His works no doubt will perpetuate his name while any taste for the fine arts remains. He was born in the island of Pomona, in Orkney, on the 14th of July 1721, being lineally descended from David Strange or Strang, a younger son of the family of the Stranges or Strangs of Balcasky, in the county of Fife, who settled in Orkney at the time of the Reformation. But as there were no males remaining of the elder branch of the Stranges of Balcasky, Sir Robert became the male representative of it, and was found by a legal investigation to have a right to the armorial bearings and every other mark of honour belonging to that ancient family. He received his classical education in Kirkwall in Orkney, under the care of a learned, worthy, and much respected gentleman, Mr Murdoch Mackenzie, who has rendered very important service to his country by the accurate surveys and charts which he has given of the islands of Orkney, and of the British and Irish coasts.

Originally intended for the law, Mr Strange soon became tired of that profession, and perceived that his genius decisively led him to the arts of drawing and engraving. For this purpose he was introduced to Mr Richard Cooper of Edinburgh, the only person there who had any taste in that department of the fine arts. He was bound with him as an apprentice for six years; during which time he made such progress in his new profession, that his friends entertained the highest expectation of his success; nor were they disappointed.

Strakes
||
Strange,
Sir Robert.

Strange,
Sir Robert.

In the year 1747 he married Isabella, only daughter of William Lumsden, son of Bishop Lumsden; and soon after his marriage he went to France, where with the most ardent application he prosecuted his studies, chiefly at Paris, under the direction of the celebrated Le Bas, who engraved many excellent prints from the Dutch painters. It was from Le Bas that he had the first hint of the use of the instrument commonly called the *dry needle*; but which he afterwards greatly improved by his own genius, and which has added such superior beauties to his engravings.

In the year 1751 Mr Strange removed with his family from Edinburgh, and settled in London, where he engraved several fine historical prints, which justly acquired to him great reputation. At this period historical engraving had made little progress in Britain, and he may be properly considered as its father. The admiration which he always had for the works of the great Italian painters made him long desire to visit Italy, the seat of the fine arts; and the farther he advanced in life, he became the more persuaded that a journey to that country was essential to an artist who had the laudable ambition to excel in his profession. He therefore undertook this journey in the year 1760. In Italy he made many admirable drawings, several of which he afterwards engraved. In Italy singular marks of attention were everywhere bestowed on Mr Strange, not only by great personages, but by the principal academies of the fine arts in that country. He was chosen a member of the academies of Rome, Florence, and Bologna, and professor in the royal academy at Parma. To show the estimation in which his talents were held at Rome, we cannot but record the following anecdote. The ceiling of the room of the Vatican library, in which the collection of engravings is kept, is elegantly painted by Signor Roffanelli. It represents the progress of engraving; and the portraits of the most eminent artists in that line are there introduced, among which is that of Strange. Under his arm he holds a portfolio, on which his name is inscribed. In France, where he resided many years at different periods, his talents likewise received every mark of attention that could be bestowed on a foreigner. He was chosen a member of the royal academy of painting at Paris. Nor was he undistinguished in his own country. He received the honour of knighthood on the 5th of January 1787.

Such was Sir Robert Strange as an artist; nor was he less distinguished by his truly amiable moral qualities, which endeared him to all who had the happiness to know him. With regard to his works, he left fifty capital plates, which have been carefully preserved in his family. They are engraved from pictures by the most celebrated painters of the Roman, Florentine, Lombard, Venetian, and other schools. They are historical both sacred and profane, poetical, allegorical.

From his earliest establishment in life, Sir Robert carefully preserved about eighty copies of the finest and most choice impressions of each plate he engraved; which, from length of time, have acquired a beauty, mellowness, and brilliancy, easier seen than described. He did this with a view of presenting them to the public at a period when age should disable him from adding to their number. These he collected into as many volumes, and arranged them in the order in which they were engraved. To each volume he prefixed two portraits of himself, on the same plate, the one an etching, the other a finished proof, from a drawing by John Baptiste Greuse. This is the last plate which he engraved, and is a proof that neither his eyes nor hand were impaired by age. It likewise shows the use he made both of aquafortis and the graver. Each volume, besides a dedication to the king, contains an introduction on the progress of engraving, and critical remarks on the pictures from which his engravings are taken. These volumes were ready to be given to the public, when Sir Robert's death

delayed this magnificent publication. He died at London, Stranraer, 5th July 1792.

The following is an authentic catalogue of his works. Plate 1. Two Heads of the Author, one an etching, the other a finished proof, from a drawing by John Baptiste Greuse; 2. The Return from Market, by Wouvermans; 3. Cupid, by Vanloo; 4. Mary Magdalen, by Guido; 5. Cleopatra, by the same; 6. The Madonna, by the same; 7. The Angel Gabriel, by the same; 8. The Virgin, holding in her hand a book, and attended by angels, by Carlo Maratt; 9. The Virgin with the Child asleep, by the same; 10. Liberty and Modesty, by Guido; 11. Apollo rewarding Merit and punishing Arrogance, by Andrea Sacchi; 12. The Finding of Romulus and Remus, by Pietro da Cortona; 13. Cæsar repudiating Pompeia, by the same; 14. Three Children of King Charles I. by Vandyke; 15. Belisarius, by Salvator Rosa; 16. St Agnes, by Dominichino; 17. The Judgment of Hercules, by Nicolas Poussin; 18. Venus attired by the Graces, by Guido; 19. and 20. Justice and Meekness, by Raffaello; 21. The Offspring of Love, by Guido; 22. Cupid Sleeping, by the same; 23. Abraham giving up the handmaid Hagar, by Guercino; 24. Esther a Suppliant before Ahasuerus, by the same; 25. Joseph and Potiphar's Wife, by Guido; 26. Venus blinding Cupid, by Titian; 27. Venus, by the same; 28. Danae, by the same; 29. Portrait of King Charles I. by Vandyke; 30. The Madonna, by Correggio; 31. St Cæcilia, by Raffaello; 32. Mary Magdalen, by Guido; 33. Our Saviour appearing to his Mother after his Resurrection, by Guercino; 34. A Mother and Child, by Parmegiano; 35. Cupid Meditating, by Schidoni; 36. Laomedon, king of Troy, detected by Neptune and Apollo, by Salvator Rosa; 37. The Death of Dido, by Guercino; 38. Venus and Adonis, by Titian; 39. Fortune, by Guido; 40. Cleopatra, by the same; 41. Two Children at School, by Schidoni; 42. Mary Magdalen, by Correggio; 43. Portrait of King Charles I. attended by the Marquis of Hamilton, by Vandyke; 44. Queen Henrietta, attended by the Prince of Wales, and holding in her arms the Duke of York, by the same; 45. Apotheosis of the Royal Children, by West; 46. The Annunciation, by Guido; 47. Portrait of Raffaello Sancio d'Urbino, by himself; 48. Sappho, by Carlo Dolci; 49. Our Saviour asleep, by Vandyke; 50. St John in the Desert, by Murillo.

STRANRAER, a seaport and royal borough, is situated on the southern shore of Lochryan, Wigtonshire, nine miles north-east of Portpatrick, and fifty south of Ayr. The town constitutes a distinct parish, and is the seat of a presbytery. It formerly belonged, in nearly equal parts, to the neighbouring parishes of Inch and Leswalt, from which it was disunited and formed into a separate parish in 1617, at which period also it was erected into a royal borough. But the town now exceeds the limits of the royal borough, and stretches into the two parishes just mentioned. Stranraer is a thriving place, and forms the emporium for the Rhyns, or western division of Wigtonshire. In 1835 there were 37 vessels belonging to it, the aggregate tonnage of which, per register, was 1789. A steam-boat has for 15 years plied weekly between Stranraer and Glasgow, and sometimes there are two or three on the passage. A high-water stone pier was built 25 years ago. The public buildings are, an elegant parish church, recently erected, four dissenting chapels, a town-hall, and a jail, which latter was formerly one of the residences of the noble family of Stair. Sir John Ross, the celebrated navigator, has a residence within the parliamentary bounds of the borough, appropriately called North-West Castle. The population in 1831 amounted to 3329, but including the suburbs, about 3800. There are no fewer than eight schools in the borough, of which six are unendowed. Stranraer has a weekly market, and several annual fairs. It unites with Whithorn, Wigton,

Strapado and New Galloway, in sending a member to parliament, and in 1839 had 219 registered voters. (C. I.)

Stratford. **STRAPADO**, or **STRAPPADO**, a kind of military punishment. The criminal's hands being tied behind him, he is hoisted up with a rope to the top of a long piece of wood, and again let fall almost to the ground; so that, by the weight of his body in the shock, his arms are dislocated. Sometimes he has to undergo three strapadoes or more.

STRASBOURG, an arrondissement of the department of the Lower Rhine, in France. It is a rich district, extending over 551 square miles, is divided into 12 cantons, and these into 162 communes, with a population of 218,839 persons. The chief city, of the same name, is also the capital of the department. It is the see of a bishop, the seat of the Lutheran consistory, and of the courts of law. The city stands in a highly cultivated plain, at the distance of about one mile from the river Rhine, on the river Ill, a small but navigable river. Its waters are distributed in various small canals through the city, and connect it with the Rhine. The streets are narrow, and the buildings for the most part old and massive, many of them very lofty. Strasburg is strongly fortified, and defended by three powerful fortresses and a strong citadel. Even in the time of peace it usually contains a garrison of 10,000. The cathedral, one of the finest Gothic buildings in France, was begun in 1275 and finished in 1439. Its tower is a most imposing object, 445 feet in height, being the loftiest erection known except the largest of the Egyptian pyramids. Besides six Catholic, there are seven Lutheran, and one Calvinist church. The other public buildings are the royal palace, the prefecture, the town-hall, the mint, and two theatres. Strasburg is the seat of a university. The population, which in 1836 amounted to 7885, is chiefly of German origin, and most of the people speak that language. The industry of the inhabitants is much exercised in making sail-cloth and other linen goods, woollens of various kinds, and in spinning and weaving cottons. There are tanneries, distilleries, founderies, paper-mills, and glass-houses; and considerable trade is carried on with Switzerland on one side, and with Germany and Holland on the other. Long. 6. 39. 31. E. Lat. 48. 34. 56. N.

STRATA, the several beds or layers of different matters whereof the earth is composed. See **MINERALOGY** and **GEOLOGY**.

STRATAGEM, in the art of war, any device for deceiving and surprising an enemy. The ancients dealt very much in stratagems, the moderns wage war more openly. Polyænus and Frontinus, the former a Greek, the latter a Latin writer, have each left a treatise on stratagems of war.

STRATEGUS, *στρατηγός*, in *Antiquity*, an officer among the Athenians, whereof there were two chosen yearly, to command the troops of the state. Plutarch avers there was one chosen from each tribe; but Pollux seems to say they were chosen indifferently from the people. The people themselves made the choice, on the last day of the year, in a place called *Pnyx*. The two *strategi* did not command together, but took their turns day by day, as we find from Herodotus and Cornelius Nepos. Constantine the Great, besides many other privileges granted to the city of Athens, honoured its chief magistrate with the title of *Μεγας Στρατηγος*, or the Great General.

STRATFORD, sometimes distinguished by the name *Long Stratford*, or *Stratford le Bow*. It is the first town in the county of Essex, on the road from London, and, being connected with Middlesex by a bridge, said to be the oldest in England, over the river Lea, may be considered as a suburb of the metropolis. It is in the hundred of Beacontree, and within the parish of West Ham. The soil is rich, but marshy, and intersected with canals and streams. Like the other suburbs of London, it has much increased

in population, as well as industrious pursuits. The East India Docks are within the parish. One of the pursuits in this place is that of practical chemistry, on a large scale, for making magnesia, the volatile salts, Prussian blue, and other preparations. There are, besides, bleachers, calico-printers, brewers, distillers, and millers. The parish of West Ham is divided into four parts, but the division of Stratford is by very far the largest, though not distinguished in the decennial population returns. The number of souls in the parish of West Ham amounted in 1801 to 6485, in 1811 to 8136, in 1821 to 9753, and in 1831 to 11,580.

STRATFORD, Fenny, a market-town in the county of Buckingham, seven miles from Stony Stratford, and forty-six from London. It is in the hundred of Newport, and is a chapelry of the parish of Blechley. Being on the great road from London to the north of England, and to Scotland, as well as to Ireland, this place chiefly depends on the money spent by travellers. It consists of one long street, on a rising ground, with the river Lofield in the bottom. There is a chapel of ease, dedicated to St Martin. The mother-church at Blechley, a mile and a half distant, is an elegant structure. There was formerly some employment in making lace, which has of late declined; but there is some trade by the Grand Junction Canal, and more is expected when the railway from London to Birmingham is completed. The population amounted in 1801 to 469, in 1811 to 481, in 1821 to 521, and in 1831 to 635, but in the whole parish to 1254.

STRATFORD, Stony, a market-town in the hundred of Newport and county of Buckingham, fifty-two miles from London. It stands on the Ouse, which divides it from Northamptonshire, and is on the Roman or Watling Street road. It is partly in the parish of Calderton, and partly in that of Wolverton, and had a church, or rather a chapel of ease, to each of these parishes, both of which were burnt in 1742; but a new one has been erected, and is a handsome structure, dedicated to St Giles. The town consists of one street, nearly a mile in length, with well-built houses on each side, mostly constructed of freestone. It has a good market on Friday, and but little trade on other days, as may be inferred from the state of its population, which amounted in 1801 to 1653, in 1811 to 1488, in 1821 to 1499, and in 1831 to 1619.

STRATFORD-ON-AVON, a town in the hundred of Barlichway and county of Warwick, ninety-four miles from London. It stands on the navigable river Avon, over which is a bridge of fourteen arches. It is moderately well built, and has some trade in corn and malt, but no manufactures. It is chiefly remarkable as the birth-place of Shakspeare, whose memory has here been celebrated by splendid pageants. In the guild-hall is a large room, called Shakspeare's, with a portrait of him and of the celebrated actor Garrick. The inhabitants amounted in 1801 to 2418, in 1811 to 2842, in 1821 to 3069, and in 1831 to 3488.

STRATH, in the Scottish language, signifies a long narrow valley, along the centre of a river.

STRATHAVEN, a town in Lanarkshire, Scotland, sixteen miles from Glasgow. It is pleasantly situated at the end of a ridge of small eminences, on the banks of the Pomilion, which runs through it, and divides it into two parts. The original part of the town is old, as is shown by its being erected into a borough of barony in the year 1450, and is most irregularly built, the streets being crowded together, and intersected by long narrow lanes. The modern part is well laid out, and in it are many excellent houses. A number of neat small villas has also been erected in the neighbourhood, by the wealthier burghesses. The old castle of Strathaven overhangs the town, and, though now in ruins, adds considerably to its beauty. The inhabitants are an industrious, enterprising class of individuals; and from their business habits they are yearly

Strathmiglo raising their town to greater importance. Considerable business is done in the cotton trade. In addition to the established church, there are chapels belonging to the Relief and United Secession bodies of dissenters. The markets for agricultural and commercial produce are well supplied. The streets and shops are lighted with gas; and in consequence of the Pomilion running through it, the supply of water has contributed greatly to its cleanliness and comfort. The population in 1821 amounted to 2866, and in 1831 it had increased to 3597, an increase caused principally by the flourishing state of its trade and manufactures.

STRATHMIGLO, a parish in Fifeshire, Scotland. In it is situated the borough of barony of the same name, erected into such in the year 1600, consisting principally of an irregular street, with lanes diverging from it at right angles, and having in the middle a town-house, with a neat tower and spire seventy feet in height. Besides a parish church, there is a place of worship belonging to the Secession body. The inhabitants are principally employed in weaving. In 1821 the population of the parish amounted to 1842, and in 1831 to 1940.

STRATHMORE, or the **GREAT STRATH**, is that district of Scotland which stretches across from the town of Stonehaven in Kincardineshire, on the east coast, to the district of Cowal in Argyleshire, on the west coast. The chain of the Grampian Mountains bounds it on the north, and the Sidlaw, Ochill, and Menteith or Lennox range of hills on the south. There is also a vale of the same name in the parish of Durness, Sutherlandshire.

STRATHSPEY is the vale of the river Spey, which runs through part of the counties of Inverness and Elgin.

STRATO, a philosopher of Lampsacus, disciple and suc-

cessor in the school of Theophrastus, about 248 years before the Christian era. He applied himself with uncommon industry to the study of nature; and after the most mature investigations, he supported that nature was inanimate, and that there was no god but nature. He was appointed preceptor to Ptolemy Philadelphus, who revered his abilities and learning, and rewarded his labours with unbounded liberality. He wrote different treatises, none of which has been preserved.

STRATON, a town of Cornwall, in the hundred of its own name, 224 miles from London. It has a market on Tuesday and another on Saturday, though both are little frequented. The inhabitants amounted in 1801 to 960, in 1811 to 1094, in 1821 to 1580, and in 1831 to 1613.

STRAUBING, a town of the kingdom of Bavaria, in the circle of the Lower Danube, the capital of the bailiwick of the same name. It is finely situated on the banks of the Danube, over which is a fine bridge. It contains seven churches, four hospitals, a gymnasium and several other schools, 700 houses, and 6800 inhabitants, who trade extensively by the river in corn and live cattle. Long. 11. 29. 28. E. Lat. 48. 52. 39. N.

STREATHAM, a town in the hundred of Brixton and county of Surrey, five miles from London, on the road to Croydon. The hamlet of Tooting is considered as a portion of it. Streatham is pleasantly situated, and contains many magnificent houses. Among others is one belonging to the duke of Bedford. The church is very neat, and was almost rebuilt in the year 1833. Near to it is a mineral spring, of aperient quality. The inhabitants amounted in 1801 to 2357, in 1811 to 2729, in 1821 to 3616, and in 1831 to 5068.

STRENGTH OF MATERIALS,

Importance **IN Mechanics**, is a subject of so much importance, that in a nation so eminent as this for invention and ingenuity in every species of manufacture, and in particular so distinguished for its improvements in machinery of every kind, it is somewhat singular that no writer has treated it in the detail which its importance and difficulty demand. The man of science who visits our great manufactories is delighted with the ingenuity which he observes in every part, the innumerable inventions which come even from individual artisans, and the determined purpose of improvement and refinement which he sees in every workshop. Every cotton-mill appears an academy of mechanical science; and mechanical invention is spreading from these fountains over the whole kingdom. But the philosopher is mortified to see this ardent spirit cramped by ignorance of principle, and many of those original and brilliant thoughts obscured and clogged with needless and even hurtful additions, and a complication of machinery which checks improvement even by its appearance of ingenuity. There is nothing in which this want of scientific education, this ignorance of principle, is so frequently observed, as in the injudicious proportion of the parts of machines and other mechanical structures; proportions and forms of parts in which the strength and position are nowise regulated by the strains to which they are exposed, and where repeated failures have been the only lessons.

Strength of materials arises from cohesion. The strength of materials arises immediately or ultimately from the cohesion of the parts of bodies. Our examination of this property of tangible matter has as yet been very partial and imperfect, and by no means enables us to apply mathematical calculations with precision and success. The various modifications of cohesion, in its different appearances of perfect softness, plasticity, ductility, elasticity,

hardness, have a mighty influence on the strength of bodies, but are hardly susceptible of measurement. Their texture, whether uniform like glass and ductile metals, crystallized or granulated like other metals and freestone, or fibrous like timber, is a circumstance no less important; yet even here, although we derive some advantage from remarking to which of these forms of aggregation a substance belongs, the aid is but small. All we can do in this want of general principles is, to make experiments on every class of bodies. Accordingly philosophers have endeavoured to instruct the public in this particular. The Royal Society of London, at its very first institution, made many experiments at their meetings, as may be seen in the first registers of the society; and since then a vast multitude of experiments have been made by public bodies and private individuals. The best of these, perhaps, up to the date of the present edition, are those of Mr Barlow.

But to make use of any experiments, there must be employed some general principle by which we can generalize their results. They will otherwise be only narrations of detached facts. We must have some notion of that intermediate, by the intervention of which an external force applied to one part of a lever, joist, or pillar, occasions a strain on a distant part. This can be nothing but the cohesion between the parts. It is this connecting force which is brought into action, or, as we more shortly express it, excited. This action is modified in every part by the laws of mechanics. It is this action which we call the *strength* of that part, and its effect is the strain on the adjoining parts; and thus it is the same force, differently viewed, that constitutes both the strain and the strength. When we consider it in the light of a resistance to fracture, we call it *strength*.

Straton
||
Strength of Materials.

Experiments to ascertain it.

Rendered useful by generalization.

Strength defined.

Strength of
Materials.
Causes
known
only from
their ef-
fects.

We call every thing a *force* which we observe ever to be accompanied by a change of motion; or, more strictly speaking, we infer the presence and agency of a force wherever we observe the state of things in respect of motion different from what we know to be the result of the action of all the forces which we know to act on the body. Thus when we observe a rope prevent a body from falling, we infer a moving force inherent in the rope, with as much confidence as when we observe it drag the body along the ground. The *immediate action* of this force is undoubtedly exerted between the immediately adjoining parts of the rope. The immediate effect is the keeping the particles of the rope together. They ought to separate by any external force drawing the ends of the rope contrariwise; and we ascribe their not doing so to a mechanical force really opposing this external force. When desired to give it a name, we name it from what we conceive to be its effect, and therefore its characteristic, and we call it *cohesion*. This is merely a name for the fact; but it is the same thing in all our denominations. We know nothing of the causes but in the effects; and our name for the cause is in fact the name of the effect, which is *cohesion*. We mean nothing else by gravitation or magnetism. What do we mean when we say that Newton understood thoroughly the nature of gravitation, of the force of gravitation; or that Franklin understood the nature of the electric force? Nothing but this: Newton considered with patient sagacity the general facts of gravitation, and has described and classed them with the utmost precision. In like manner, we shall understand the nature of cohesion when we have discovered with equal generality the laws of cohesion, or general facts which are observed in the appearances, and when we have described and classed them with equal accuracy.

Let us therefore attend to the more simple and obvious phenomena of cohesion, and mark with care every circumstance of resemblance by which they may be classed. Let us receive these as the laws of cohesion, characteristic of its supposed cause, the force of cohesion. We cannot pretend to enter on this vast research. The modifications are innumerable; and it would require the penetration of more than Newton to detect the circumstance of similarity amidst millions of discriminating circumstances. Yet this is the only way of discovering which are the primary facts characteristic of the force, and which are the modifications. The study is immense, but it is by no means desperate; and we entertain great hopes that it will ere long be successfully prosecuted; but, in our particular predicament, we must content ourselves with selecting such general laws as seem to give us the most immediate information of the circumstances that must be attended to by the mechanic in his constructions, that he may unite strength with simplicity, economy, and energy.

All bodies
elastic.

1. Then, it is a matter of fact that all bodies are in a certain degree perfectly elastic; that is, when their form or bulk is changed by certain moderate compressions or distractions, it requires the continuance of the changing force to continue the body in this new state; and when the force is removed, the body recovers its original form. We limit the assertion to *certain moderate* changes. For instance, take a lead wire of one fifteenth of an inch in diameter and ten feet long; fix one end firmly to the ceiling, and let the wire hang perpendicular; affix to the lower end an index like the hand of a watch; on some stand immediately below let there be a circle divided into degrees, with its centre corresponding to the lower point of the wire; now turn this index twice round, and thus twist the wire. When the index is let go, it will turn backwards again, by the wire untwisting itself, and make almost four revolutions before it stops; after which it twists and untwists many times, the index going backwards and forwards round the circle, diminishing, however, its arch of twist

each time, till at last it settles precisely in its original position. This may be repeated for ever. Now, in this motion, every part of the wire partakes equally of the twist. The particles are stretched, require force to keep them in their state of extension, and recover completely their relative positions. These are all the characters of what the mechanician calls *perfect elasticity*. This is a quality quite familiar in many cases, as in glass, tempered steel, &c., but was thought incompetent to lead, which is generally considered as having little or no elasticity. But we make the assertion in the most general terms, with the limitation to moderate derangement of form. We have made the same experiment on a thread of pipe-clay, made by forcing soft clay through the small hole of a syringe by means of a screw, and we found it more elastic than the lead wire; for a thread of one twentieth of an inch diameter and seven feet long allowed the index to make two turns, and yet completely recovered its first position.

2. But if we turn the index of the lead wire four times round, and let it go again, it untwists again in the same manner, but it makes little more than four turns back again; and after many oscillations it finally stops in a position almost two revolutions removed from its original position. It has now acquired a new arrangement of parts, and this new arrangement is permanent like the former; and, what is of particular moment, it is perfectly elastic. This change is familiarly known by the denomination of a *set*. The wire is said to have *taken a set*. When we attend minutely to the procedure of nature in this phenomenon, we find that the particles have, as it were, slid on each other, still cohering, and have taken a new position, in which their connecting forces are in equilibrio; and in this change of relative situation, it appears that the connecting forces which maintained the particles in their first situation were not in equilibrio in some position intermediate between that of the first and that of the last form. The force required for changing this first form augmented with the change, but only to a certain degree; and during this process the connecting forces always tended to the recovery of this first form. But after the change of mutual position has passed a certain magnitude, the union has been partly destroyed, and the particles have been brought into new situations; such, that the forces which now connect each with its neighbour tend, not to the recovery of the first arrangement, but to push them farther from it, into a new situation, to which they now verge, and require force to prevent them from acquiring. The wire is now in fact again perfectly elastic; that is, the forces which now connect the particles with their neighbours, augment to a certain degree as the derangement from this new position augments. This is not reasoning from any theory. It is narrating facts, on which a theory is to be founded. What we have been just now saying, is evidently a description of that sensible form of tangible matter which we call *ductility*. It has every gradation of variety, from the softness of butter to the firmness of gold. All these bodies have some elasticity; but we say they are not perfectly elastic, because they do not completely recover their original form when it has been greatly damaged. The whole gradation may be most distinctly observed in a piece of glass or hard sealing-wax. In the ordinary form glass is perhaps the most completely elastic body that we know, and may be bent till just ready to snap, and yet completely recovers its first form, and takes no set whatever; but when heated to such a degree as just to be visible in the dark, it loses its brittleness, and becomes so tough that it cannot be broken by any blow; but it is no longer elastic, it takes any set, and keeps it. When more heated, it becomes as plastic as clay; but in this state is remarkably distinguished from clay by a quality which we may call *viscosity*, which is something like elasticity, of which clay and other bodies purely plastic exhibit no appearance. This

Strength of
Materials.

What is
meant by
a set.

Ductility.

Viscosity.

Strength of
Materials.

is the joint operation of strong adhesion and softness. When a rod of perfectly soft glass is suddenly stretched a little, it does not at once take the shape which it acquires after some little time. It is owing to this that, in taking the impression of a seal, if we take off the seal while the wax is yet very hot, the sharpness of the impression is immediately destroyed. Each part drawing its neighbour, and each part yielding, the prominent parts are pulled down and blunted, and the sharp hollows are pulled upwards and also blunted. The seal must be kept on till the wax has become not only stiff, but hard.

Observed
in all ho-
mogeneous
plastic bo-
dies.

This viscosity is to be observed in all plastic bodies which are homogeneous. It is not observed in clay, because clay is not homogeneous, but consists of hard particles of argillaceous earth sticking together by their attraction for water. Something like it might be made of finely powdered glass and a clammy fluid such as turpentine. Viscidity has all degrees of softness, till it degenerates to ropy fluidity like that of olive oil. Perhaps something of it may be found even in the most perfect fluid with which we are acquainted, as we observed in the experiments for ascertaining specific gravity.

When ductility and elasticity are combined in different proportions, an immense variety of sensible modes of aggregation may be produced. Some degree of both are probably to be observed in all bodies of complex constitution; that is, which consist of particles made up of many different kinds of atoms. Such a constitution of a body must afford many situations permanent, but easily deranged.

Particles
acted on by
attractions
and repul-
sions.

In all these changes of disposition which take place among the particles of a ductile body, the particles are at such distance that they still cohere. The body may be stretched a little; and on removing the extending force, the body shrinks into its first form. It also resists moderate compressions; and when the compressing force is removed, the body again swells out. Now the corpuscular *fact* here is, that the particles are acted on by attractions and repulsions, which balance each other when no external force is acting on the body, and which augment as the particles are made, by any external cause, to recede from this situation of mutual inactivity; for since force is requisite to produce either the dilatation or the compression, and to maintain it, we are obliged, by the constitution of our minds, to infer that it is opposed by a force accompanying or inherent in every particle of dilatable or compressible matter; and as this necessity of employing force to produce a change indicates the agency of these corpuscular forces, and marks their kind, according as the tendencies of the particles appear to be toward each other in dilatation, or from each other in compression; so it also measures the degrees of their intensity. Should it require three times the force to produce a double compression, we must reckon the mutual repulsions triple when the compression is doubled; and so in other instances. We see from all this that the phenomena of cohesion indicate some relation between the centres of the particles. To discover this relation is the great problem in corpuscular mechanism, as it was in the Newtonian investigation of the force of gravitation. Could we discover this law of action between the corpuscles with the same certainty and distinctness, we might with equal confidence say what will be the result of any position which we give to the particles of bodies; but this is beyond our hopes. The law of gravitation is so simple, that the discovery or detection of it amid the variety of celestial phenomena required but one step; and in its own nature its possible combinations still do not greatly exceed the powers of human research. One is almost disposed to say that the Supreme Being has exhibited it to our reasoning powers as sufficient to employ with success our utmost efforts, but not so abstruse as to discourage us from the noble attempt. It seems to be otherwise with respect to cohesion. Mathematics informs us, that if it deviates sensibly from the

The great
problem in
corpuscu-
lar mecha-
nism.

law of gravitation, the simplest combinations will make the joint action of several particles an almost impenetrable mystery. We must therefore content ourselves, for a long time to come, with a careful observation of the simplest cases that we can propose, and with the discovery of secondary laws of action, in which many particles combine their influence. In pursuance of this plan, we observe,

3. That whatever is the situation of the particles of a body with respect to each other, when in a quiescent state, they are kept in these situations by the balance of opposite forces. This cannot be refused, nor can we form to ourselves any other notion of the state of the particles of a body. Whether we suppose the ultimate particles to be of certain magnitudes and shapes, touching each other in single points of cohesion; or whether, with Boscovich, we consider them as at a distance from each other, and acting on each other by attractions and repulsions, we must acknowledge, in the first place, that the centres of the particles (by whose mutual distances we must estimate the distance of the particles) may and do vary their distances from each other. What else can we say when we observe a body increase in length, in breadth, and thickness, by heating it, or when we see it diminish in all these dimensions by an external compression? A particle, therefore, situated in the midst of many others, and remaining in that situation, must be conceived as maintained in it by the mutual balancing of all the forces which connect it with its neighbours. It is like a ball kept in its place by the opposite

Particles
kept in
their places
by a bal-
ance of
forces.

action of two springs. This illustration merits a more particular application. Suppose a number of balls ranged on the table in the angles of equilateral triangles, and that each ball is connected with the six which lie around it by means of an elastic wire curled like a cork-screw; suppose such another stratum of balls above this, and parallel to it, and so placed that each ball of the upper stratum is perpendicularly over the centre of the equilateral triangle below, and let these be connected with the balls of the under stratum by similar spiral wires. Let there be a third and a fourth, and any number of such strata, all connected in the same manner. It is plain that this may extend to any size, and fill any space. Now let this assemblage of balls be firmly contemplated by the imagination, and be supposed to shrink continually in all its dimensions, till the balls, and their distances from each other, and the connecting wires, all vanish from the sight as discrete individual objects. All this is very conceivable. It will now appear like a solid body, having length, breadth, and thickness; it may be compressed, and will again resume its dimensions; it may be stretched, and will again shrink; it will move away when struck; in short, it will not differ in its sensible appearance from a solid elastic body. Now when this body is in a state of compression, for instance, it is evident that any one of the balls is at rest, in consequence of the mutual balancing of the actions of all the spiral wires which connect it with those around it. It will greatly conduce to the full understanding of all that follows to recur to this illustration. The analogy or resemblance between the effects of this constitution of things and the effects of the corpuscular forces is very great; and wherever it obtains, we may safely draw conclusions from what we know would be the condition of a body of common tangible matter. We shall just give one instructive example, and then have done with this hypothetical body. We can suppose it

Illustra-
tion of this
proposi-
tion.

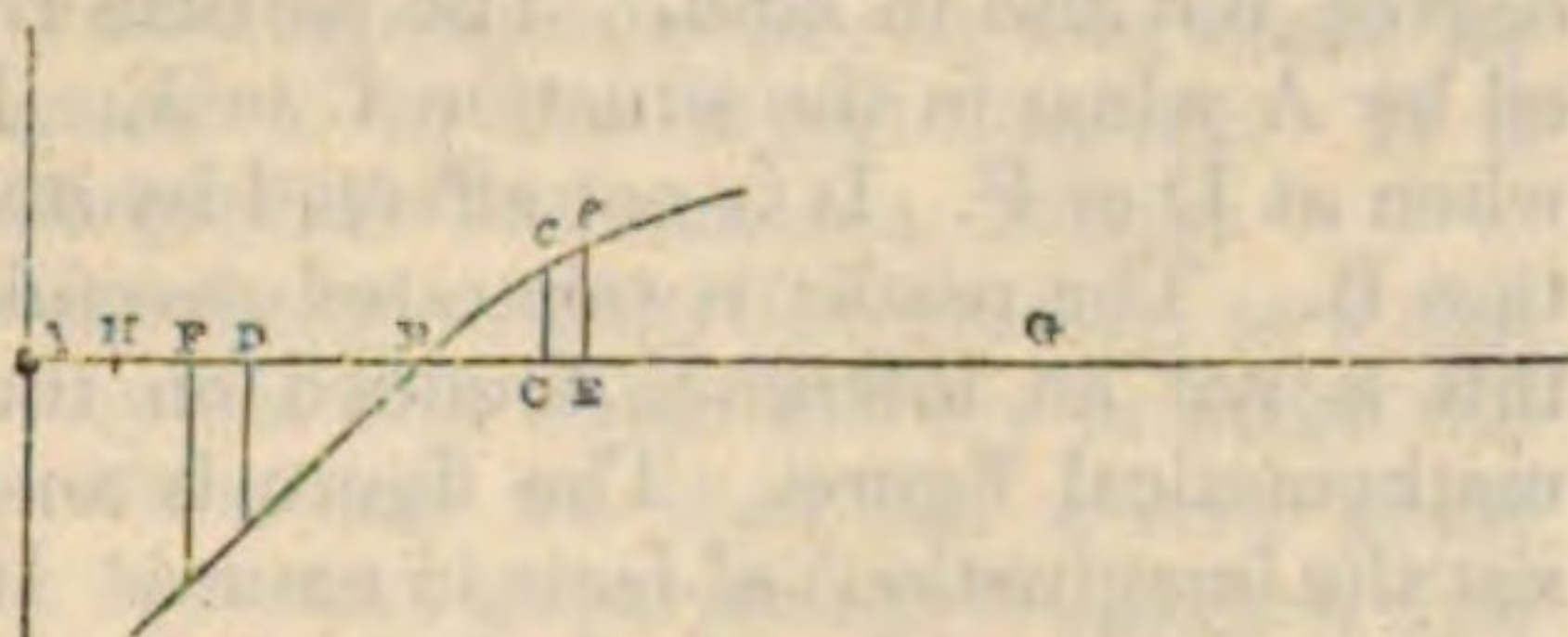
of a long shape, resting on one point; we can suppose two weights A, B, suspended at the extremities, and the whole in equilibrio. We commonly express this state of things by saying that A and B are in equilibrio. This is very inaccurate. A is in fact in equilibrio with the united action of all the springs which connect the ball to which it is applied with the adjoining balls. These springs are brought into action, and each is in equilibrio with the joint action of

By exam-
ple.

Strength of Materials. all the rest. Thus through the whole extent of the hypothetical body the springs are brought into action in a way and in a degree which mathematics can easily investigate. We need not do this: it is enough for our purpose that our imagination readily discovers that some springs are stretched, others are compressed, and that a pressure is excited on the middle point of support, and the support exerts a reaction which precisely balances it; and the other weight is, in like manner, in immediate equilibrio with the equivalent of the actions of all the springs which connect the last ball with its neighbours. Now take the analogical or resembling case, an oblong piece of solid matter, resting on a fulcrum, and loaded with two weights in equilibrio; for the actions of the connecting springs substitute the corpuscular forces; and the result will resemble that of the hypothesis.

Now, as there is something that is at least analogous to a change of distance of the particles, and a concomitant change of the intensity of the connecting forces, we may express this in the same way that we are accustomed to do in similar cases. Let A and B (fig. 1) represent the centres of two particles of a coherent elastic body in their quiescent inactive state, and let us consider only the mechanical condition of B. The

Fig. 1.



body may be stretched. In this case the distance AB of the particles may become AC. In this state there is something which makes it necessary to employ a force to keep the particles at this distance. C has a tendency towards A, or we may say that A attracts C. We may represent the magnitude of this tendency of C towards A, or this attraction of A, by a line Cc perpendicular to AC. Again, the body may be compressed, and the distance AB may become AD. Something obliges us to employ force to continue this compression, and D tends from A, or A appears to repel D. The intensity of this tendency or repulsion may be represented by another perpendicular Dd; and, to represent the different directions of these tendencies, or the different nature of these actions, we may set Dd on the opposite side of AB. It is in this manner that Boscovich has represented the actions of corpuscular forces in his celebrated Theory of Natural Philosophy. Newton had said, that as the great movements of the solar system were regulated by forces operating at a distance, and varying with the distance, so he strongly suspected (*valde suspicor*) that all the phenomena of cohesion, with all its modifications in the different sensible forms of aggregation, and in the phenomena of chemistry and physiology, resulted from the similar agency of forces varying with the distance of the particles. The learned Jesuit pursued this thought; and has shown, that if we suppose an ultimate atom of matter endowed with powers of attraction and repulsion, varying, both in kind and degree, with the distance, and if this force be the same in every atom, it may be regulated by such a relation to the distance from the neighbouring atom, that a collection of such may have all the sensible appearance of bodies in their different forms of solids, liquids, and vapours, elastic or unelastic, and endowed with all the properties which we perceive, by whose immediate operation the phenomena of motion by impulse, and all the phenomena of chemistry, and of animal and vegetable economy, may be produced. He shows, that notwithstanding a perfect sameness, and even a great simplicity, in this atomical constitution, there will result from this union all that unspeakable variety of form and property which diversifies and embellishes the face of

Strength of Materials. nature. We shall take another opportunity of giving such an account of this celebrated work as it deserves. We mention it only by the by, as far as a general notion of it will be of some service on the present occasion. For this purpose, we just observe that Boscovich conceives a particle of any individual species of matter to consist of an unknown number of particles of simpler constitution; each of which particles, in their turn, is compounded of particles still more simply constituted, and so on through an unknown number of orders, till we arrive at the simplest possible constitution of a particle of tangible matter, susceptible of length, breadth, and thickness, and necessarily consisting of four atoms of matter. And he shows that the more complex we suppose the constitution of a particle, the more must the sensible qualities of the aggregate resemble the observed qualities of tangible bodies. In particular, he shows how a particle may be so constituted, that although it act on one other particle of the same kind through a considerable interval, the interposition of a third particle of the same kind may render it totally, or almost totally, inactive; and therefore an assemblage of such particles would form such a fluid as air. All these curious inferences are made with uncontrovertible evidence; and the greatest encouragement is thus given to the mathematical philosopher to hope, that by cautious and patient proceeding in this way, we may gradually approach to a knowledge of the laws of cohesion, that will not shun a comparison even with the Principia of Newton. No step can be made in this investigation, but by observing with care, and generalizing with judgment, the phenomena, which are abundantly numerous, and much more at our command than those of the great and sensible motions of bodies. Following this plan, we observe,

4. It is a matter of fact, that every body has some degree of compressibility and dilatability; and when the changes of dimension are so moderate that the body completely recovers its original dimensions on the cessation of the changing force, the extensions or compressions are sensibly proportional to the extending or compressing forces; and therefore the connecting forces are proportional to the distances of the particles from their quiescent, neutral, or inactive positions. This seems to have been first viewed as a law of nature by the penetrating eye of Dr Robert Hooke, one of the most eminent philosophers of the last century. He published a cipher, which he said contained the theory of springiness and of the motions of bodies by the action of springs. It was this, *ceiinoosssttu*. When explained in his dissertation, published some years after, it was *ut tensio sic vis*. This is precisely the proposition now asserted as a general fact, a law of nature. This dissertation is full of curious observations of facts in support of his assertion. In his application to the motion of bodies, he gives his noble discovery of the balance-spring of a watch, which is founded on this law. The spring, as it is more and more coiled up, or unwound, by the motion of the balance, acts on it with a force proportional to the distance of the balance from its quiescent position. The balance, therefore, is acted on by an accelerating force, which varies in the same manner as the force of gravity acting on a pendulum swinging in a cycloid. Its vibrations therefore must be performed in equal time, whether they are wide or narrow. In the same dissertation Hooke mentions all the facts which John Bernoulli afterwards adduced in support of Leibnitz's whimsical doctrine of the force of bodies in motion, as the doctrine of the *vires vivæ*; a doctrine which Hooke might justly have claimed as his own, had he not seen its futility.

Experiments made since the time of Hooke show that this law is strictly true in the extent to which we have limited it, viz. in all the changes of form which will be completely undone by the elasticity of the body. It is nearly true to a much greater extent. James Bernoulli, in his dis-

How Boscovich represents the action of corpuscular forces.

Every body of compressibility and dilatability; and when the changes of dimension are so moderate that the body completely recovers its original dimensions on the cessation of the changing force, the extensions or compressions are sensibly proportional to the extending or compressing forces; and therefore the connecting forces are proportional to the distances of the particles from their quiescent, neutral, or inactive positions. This seems to have been first viewed as a law of nature by the penetrating eye of Dr Robert Hooke, one of the most eminent philosophers of the last century. He published a cipher, which he said contained the theory of springiness and of the motions of bodies by the action of springs. It was this, *ceiinoosssttu*. When explained in his dissertation, published some years after, it was *ut tensio sic vis*. This is precisely the proposition now asserted as a general fact, a law of nature. This dissertation is full of curious observations of facts in support of his assertion. In his application to the motion of bodies, he gives his noble discovery of the balance-spring of a watch, which is founded on this law. The spring, as it is more and more coiled up, or unwound, by the motion of the balance, acts on it with a force proportional to the distance of the balance from its quiescent position. The balance, therefore, is acted on by an accelerating force, which varies in the same manner as the force of gravity acting on a pendulum swinging in a cycloid. Its vibrations therefore must be performed in equal time, whether they are wide or narrow. In the same dissertation Hooke mentions all the facts which John Bernoulli afterwards adduced in support of Leibnitz's whimsical doctrine of the force of bodies in motion, as the doctrine of the *vires vivæ*; a doctrine which Hooke might justly have claimed as his own, had he not seen its futility.

Strength of Materials. sertation on the elastic curve, relates some experiments of his own, which seem to deviate considerably from it; but on close examination they do not. The finest experiments are those of Coulomb, published in some late volumes of the Memoirs of the Academy of Paris. He suspended balls by wires, and observed their motions of oscillation, which he found accurately corresponding with this law.

This we shall find to be a very important fact in the doctrine of the strength of bodies, and we desire the reader to make it familiar to his mind. If we apply to this our manner of expressing these forces by perpendicular ordinates Ce , Dd (fig. 1), we must take other situations E , F , of the particle B , and draw Ee , Ff ; and we must have $Dd : Ff = BD : BF$, or $Cc : Ee = BC : BE$. In such a supposition $FdBce$ must be a straight line. But we shall have abundant evidence by and by that this cannot be strictly true, and that the line Bce , which limits the ordinates expressing the attractive forces, becomes concave towards the line ABE , and that the part Bdf is convex towards it. All that can be safely concluded from the experiments hitherto made is, that *to a certain extent* the forces, both attractive and repulsive, are *sensibly* proportional to the dilatations and compressions. For,

When a body is much dilated, a small addition of force will increase its dilatation.

5. It is universally observed, that when the dilatations have proceeded a certain length, a less addition of force is sufficient to increase the dilatation in the same degree. This is always observed when the body has been so far stretched that it takes a set, and does not completely recover its form. The like may be generally observed in compressions. Most persons will recollect, that in violently stretching an elastic cord, it becomes suddenly weaker, or more easily stretched. But these phenomena do not positively prove a diminution of the corpuscular force acting on one particle: it more probably arises from the disunion of some particles whose action contributed to the whole or sensible effect. And in compressions we may suppose something of the same kind; for when we compress a body in one direction, it commonly bulges out in another; and in cases of very violent action some particles may be disunited, whose transverse action had formerly balanced *part* of the compressing force. For the reader will see on reflection, that since the compression in one direction causes the body to bulge out in the transverse direction, and since this bulging out is in opposition to the transverse forces of attraction, it must employ some part of the compressing force. And the common appearances are in perfect uniformity with this conception of things. When we press a bit of dryish clay, it swells out and cracks transversely. When a pillar of wood is overloaded, it swells out, and small crevices appear in the direction of the fibres. After this it will not bear half of the load. This the carpenters call *crippling*; and a knowledge of the circumstances which modify it is of great importance, and enables us to understand some very paradoxical appearances, as will be shown by and by.

This partial disuniting of particles formerly cohering, is, we imagine, the chief reason why the totality of the forces which really oppose an external strain does not increase in the proportion of the extensions and compressions. But sufficient evidence will also be given that the forces which would connect one particle with one other particle do not augment in the accurate proportion of the change of distance; that in extensions they increase more slowly, and in compressions more rapidly.

Ductility another cause of deviation.

But there is another cause of this deviation perhaps equally effectual with the former. Most bodies manifest some degree of ductility. Now what is this? The fact is, that the parts have taken a new arrangement, in which they again cohere. Therefore, in the passage to this new arrangement, the sensible forces, which are the joint result of many corpuscular forces, begin to respect this new arrange-

ment instead of the former. This must change the simple law of corpuscular force, characteristic of the particular species of matter under examination. It does not require much reflection to convince us that the possible arrangements which the particles of a body may acquire, without appearing to change their nature, must be more numerous according as the particles are of a more complex constitution; and it is reasonable to suppose that the constitution even of the most simple kind of matter that we are acquainted with is exceedingly complex. Our microscopes show us animals so minute, that a heap of them must appear to the naked eye an uniform mass with a grain finer than that of the finest marble or razor hone; and yet each of these has not only limbs, but bones, muscular fibres, blood-vessels, fibres, and a blood consisting in all probability of globules organized and complex like our own. The imagination is here lost in wonder; and nothing is left us but to adore inconceivable art and wisdom, and to exult in the thought that we are the only spectators of this beautiful scene who can derive pleasure from the view. But let us proceed to observe,

6. That the forces which connect the particles of tangible bodies change by a change of distance, not only in degree, but also in kind. The particle B (fig. 1) is attracted by A when in the situation C or E . It is repelled by it when at D or F . It is not affected by it when in the situation B . The reader is requested carefully to remark, that this is not an inference founded on the authority of our mathematical figure. The figure is an expression (to assist the imagination) of facts in nature. It requires no force to keep the particles of a body in their quiescent situations: but if they be separated by stretching the body, they endeavour (pardon the figurative expression) to come together again. If they be brought nearer by compression, they endeavour to recede. This endeavour is manifested by the necessity of employing force to maintain the extension or condensation; and we represent this by the different position of our lines. But this is not all: the particle B , which is repelled by A when in the situation F or D , is neutral when at B , and is attracted when at C or E , may be placed at such a distance AG from A greater than AB that it shall be again repelled, or at such a distance AH that it shall be again attracted; and these alterations may be repeated again and again. This is curious and important, and requires something more than a bare assertion for its proof.

In the article OPTICS we mentioned the most curious and valuable observations of Sir Isaac Newton, by which it appears that light is thus alternately attracted and repelled by bodies. The rings of colour which appear between the object-glasses of long telescopes showed, that in the small interval of $\frac{1}{1000}$ th of an inch, there are at least an hundred such changes observable, and that it is highly probable that these alternations extend to a much greater distance. At one of these distances the light actually converges towards the solid matter of the glass, which we express shortly by saying that it is attracted by it, and that at the next distance it declines from the glass, or is repelled by it. The same thing is more simply inferred from the phenomena of light passing by the edges of knives and other opaque bodies. We refer the reader to the experiments themselves, the detail being too long for this place; and we request him to consider them minutely and attentively, and to form distinct notions of the inferences drawn from them. And we desire it to be remarked, that although Newton, in his discussion, always considers light as a set of corpuscles moving in free space, and obeying the actions of external forces like any other matter, the particular conclusion in which we are just now interested does not at all depend on this notion of the nature of light. Should we, with Descartes or Huygens, suppose light to be the undulation of an elastic medium, the

Strength of Materials.

The forces which connect the particles of tangible bodies change by a change of distance.

Light alternately attracted and repelled.

Strength of Materials. conclusion will be the same. The undulations at certain distances are disturbed by forces directed towards the body, and at a greater distance the disturbing forces tend from the body.

The same alternations of attraction and repulsion observable in the particles of other bodies, as glass. But the same alternations of attraction and repulsion may be observed between the particles of common matter. If we take a piece of very flat and well-polished glass, such as is made for the horizon-glasses of a good Hadley's quadrant, and if we wrap round it a fibre of silk as it comes from the cocoon, taking care that the fibre shall nowhere cross another, and then press this pretty hard on such another piece of glass, it will lift it up and keep it suspended. The particles therefore of the one do most certainly attract those of the other, and this at a distance equal to the thickness of the silk fibre. This is nearly the limit; and it sometimes requires a considerable pressure to produce the effect. The pressure is effectual only by compressing the silk fibre, and thus diminishing the distance between the glass plates. This adhesion cannot be attributed to the pressure of the atmosphere, because there is nothing to hinder the air from insinuating itself between the plates, since they are separated by the silk. Besides, the experiment succeeds equally well under the receiver of an air-pump. This most valuable experiment was first made by Huygens, who reported it to the Royal Society. It is narrated in the Philosophical Transactions, No. 86.

Here, then, is an attraction acting, like gravity, at a distance. But take away the silk fibre, and try to make the glasses touch each other, and we shall find a very great force necessary. By Newton's experiments it appears, that unless the prismatic colours begin to appear between the glasses, they are at least $\frac{1}{890}$ th of an inch asunder or more. Now we know that a very considerable force is necessary for producing these colours, and that the more we press the glasses together the more rings of colours appear. It also appears from Newton's measures, that the difference of distance between the glasses where each of these colours appears is about the 89,000th part of an inch. We know further, that when we have produced the last appearance of a greasy or pearly colour, and then augment the pressure, making it about 1000 pounds on the square inch, all colours vanish, and the two pieces of glass seem to make one transparent undistinguishable mass. They appear now to have no air between them, or to be in mathematical contact. But another fact shows this conclusion to be premature. The same circles of colours appear in the top of a soap-bubble; and as it grows thinner at top, there appears an unreflecting spot in the middle. We have the greatest probability therefore that the perfect transparency in the middle of the two glasses does not arise from their being in contact, but because the thickness of air between them is too small in that place for the reflection of light. Nay, Newton expressly found no reflection where the thickness was $\frac{2}{3}$ ths or more of the $\frac{1}{89000}$ th part of an inch.

All this while the glasses are strongly repelling each other, for great pressure is necessary for continuing the appearance of those colours, and they vanish in succession as the pressure is diminished. This vanishing of the colours is a proof that the glasses are moving off from each other, or repelling each other. But we can put an end to this repulsion by very strong pressure, and at the same time sliding the glasses on each other. We do not pretend to account for this effect of the sliding motion; but the fact is, that by so doing, the glasses will cohere with very great force, so that we shall break them by any attempt to pull them asunder. It commonly happens (at least it did so with us), that in this sliding compression of two smooth flat plates of glass, they scratch and mutually destroy each other's surface. It is also worth remarking, that different kinds of glass exhibit different properties in this respect.

Flint glass will attract even though a silk fibre lies double between them, and they much more readily cohere by this sliding pressure. Strength of Materials.

Here, then, are two distances at which the plates of glass attract each other; namely, when the silk fibre is interposed, and when they are forced together with this sliding motion. And in any intermediate situation they repel each other. We see the same thing in other solid bodies. Two pieces of lead, made perfectly clean, may be made to cohere by grinding them together in the same manner. Lead and iron. It is in this way that pretty ornaments of silver are united to iron. The piece is scraped clean, and a small bit of silver like a fish scale is laid on. The die which is to strike it into a flower or other ornament is then set on it, and we give it a smart blow, which forces the metals into contact as firm as if they were soldered together. It sometimes happens that the die adheres to the coin so that they cannot be separated: and it is found that this frequently happens when the engraving is such that the raised figure is not completely surrounded with a smooth flat ground. The probable cause of this is curious. When the coin has a flat surface all around, this is produced by the most prominent part of the die. This applies to the metal, and completely confines the air which filled the hollow of the die. As the pressure goes on, the metal is squeezed up into the hollow of the die; but there is still air compressed between them, which cannot escape by any passage. It is therefore prodigiously condensed, and exerts an elasticity proportioned to the condensation. This serves to separate the die from the metal when the stroke is over. The hollow part of the die has not touched the metal all the while, and we may say that the impression was made by air. If this air escape by any engraving reaching through the border, they cohere inseparably. Probable cause why the die adheres to the coin.

We have admitted that the glass plates are in contact when they adhere thus firmly. But we are not certain of this: for if we take these cohering glasses, and touch them with water, it quickly insinuates itself between them. Yet they still cohere, but can now be pretty easily separated.

It is owing to this repulsion, exerted through its proper sphere, that certain powders swim on the surface of water, and are wetted with great difficulty. Certain insects can run about on the surface of water. They have brushy feet, which occupy a considerable surface, and if their steps be viewed with a magnifying glass, the surface of the water is seen depressed all around, resembling the footsteps of a man walking on feather beds. This is owing to a repulsion between the brush and the water. A common fly cannot walk in this manner on water. Its feet are wetted, because they attract the water instead of repelling it. A steel needle, slightly greased, will lie on the surface of water, make an impression as a great bar would make on a feather bed; and its weight is less than that of the displaced water. A dew-drop lies on the leaves of plants without touching them mathematically, as is plain from the extreme brilliancy of the reflection at the posterior surface; nay, it may be sometimes observed that the drops of rain lie on the surface of water, and roll about on it like balls on a table. Yet all these substances can be wetted; that is, water can be applied to them at such distances that they attract it. Repulsion the cause of some bodies swimming in a fluid specifically lighter than themselves.

What we lately remarked of water insinuating itself between the glass plates without altogether destroying their cohesion, shows that this cohesion is not the same that obtains between the particles of one of the plates; that is, the two plates are not in the state of one continued mass. It is highly probable, therefore, that between these two states there is an intermediate state of repulsion, nay, perhaps, many such, alternated with attractive states.

A piece of ice is elastic, for it rebounds and rings. Its particles, therefore, when compressed, resile; and when

Strength of Materials. stretched, contract again. The particles are therefore in the state represented by B in figure 1, acted on by repulsive forces if brought nearer, and by attractive forces if drawn further asunder. Ice expands, like all other bodies, by heat. It absorbs a vast quantity of fire, which, by combining its attractions and repulsions with those of the particles of ice, changes completely the law of action, and the ice becomes water. In this new state the particles are again in limits between attractive and repulsive forces; for water has been shown, by the experiments of Canton and Zimmerman, to be elastic or compressible. It again expands by heat. It again absorbs a prodigious quantity of heat, and becomes elastic vapour; its particles repelling each other at all distances yet observed. The distance between the particles of one plate of glass and those of another which lies on it, and is carried by it, is a distance of repulsion; for the force which supports the upper piece is acting in opposition to its weight. This distance is less than that at which it would *suspend* it below it with a silk fibre interposed; for no prismatic colours appear between them when the silk fibre is interposed. But the distance at which glass attracts water is much less than this, for no colours appear when glass is wetted with water. This distance is less, and not greater, than the other; for when the glasses have water interposed between them instead of air, it is found, that when any particular colour appears, the thickness of the plate of water is to that of the plate of air which would produce the same colour, nearly as three to four. Now, if a piece of glass be wetted, and exhibit no colour, and another piece of glass be simply laid on it, no colour will appear; but if they are strongly pressed, the colours appear in the same manner as if the glasses had air between. Also, when glass is simply wetted, and the film of water is allowed to evaporate, when it is thus reduced to a proper thinness the colours show themselves in great beauty.

Particles of matter connected by forces acting at a distance. These are a few of many thousand facts, by which it is unquestionably proved that the particles of tangible matter are connected by forces acting at a distance, varying with the distance, and alternately attractive and repulsive. If we represent these forces, as we have already done in fig. 1, by the ordinates Cc, Dd, Ee, Ff, &c. of a curve, it is evident that this curve must cross the axis at all those distances where the forces change from attractive to repulsive, and the curve must have branches alternately above and below the axis.

All these alternations of attraction and repulsion take place at small and insensible distances. At all sensible distances the particles are influenced by the attraction of gravitation; and therefore this part of the curve must be a

hyperbola whose equation is $y = \frac{a^3}{x^2}$. What is the form of

the curve corresponding to the smallest distance of the particles? that is, what is the mutual action between the particles just before their coming into absolute contact? Analogy should lead us to suppose it to be repulsion; for solidity is the last and simplest form of bodies with which we are acquainted. Fluids are more compounded, containing fire as an essential ingredient. We should conclude that this ultimate repulsion is insuperable, for the hardest bodies are the most elastic. We are fully entitled to say that this repelling force exceeds all that we have ever yet applied to overcome it; nay, there are good reasons for saying that this ultimate repulsion, by which the particles are kept from mathematical contact, is really insuperable in its own nature, and that it is impossible to produce mathematical contact.

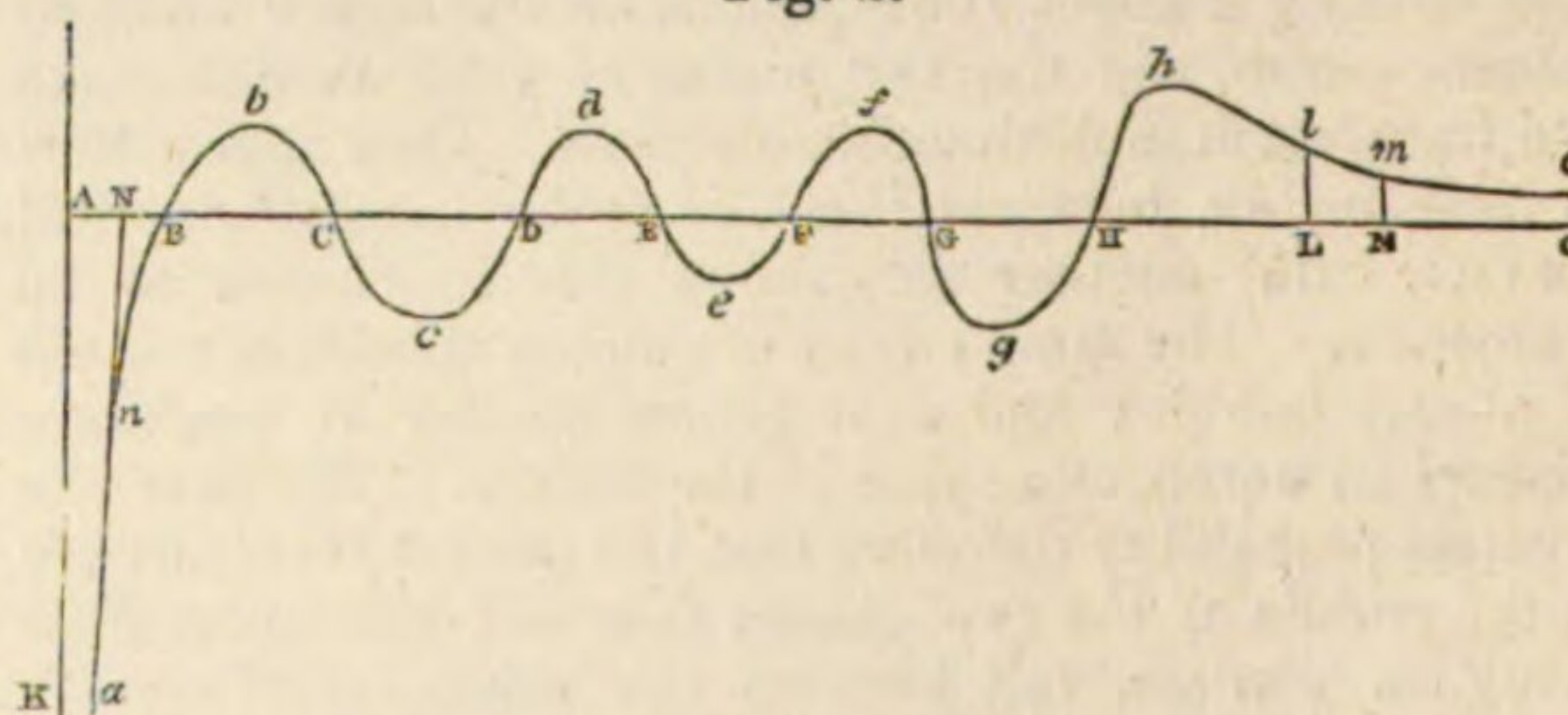
Mathematical contact impossible. We shall just mention one of these, which we consider as unanswerable. Suppose two atoms, or ultimate particles of matter, A and B. Let A be at rest, and B move up to it with the velocity 2; and let us suppose that it comes into

mathematical contact, and impels it (according to the common acceptance of the word). Both move with the velocity 1. This is granted by all to be the final result of the collision. Now the instant of time in which this communication happens is no part either of the duration of the solitary motion of A, nor of the joint motion of A and B: it is the separation or boundary between them. It is at once the end of the first and the beginning of the second, belonging equally to both. A was moving with the velocity 2. The distinguishing circumstance, therefore, of its mechanical state is, that it has a determination (however incomprehensible) by which it would move for ever with the velocity 2, if nothing changed it. This it has during the whole of its solitary motion, and therefore in the last instant of this motion. In like manner, during the whole of the joint motion, and therefore in the first instant of this motion, the atom A has a determination by which it would move for ever with the velocity 1. In one and the same instant, therefore, the atom A has two incompatible determinations. Whatever notion we can form of this state, which we call velocity, as a distinction of condition, the same impossibility of conception, or the same absurdity, occurs. Nor can it be avoided in any other way than by saying, that this change of A's motion is brought about by insensible gradations; that is, that A and B influence each other precisely as they would do if a slender spring were interposed. The reader is desired to look at what we have said in the article PHYSICS.

The two magnets there spoken of are good representatives of two atoms endowed with mutual powers of repulsion; and the communication of motion is accomplished in both cases in precisely the same manner.

If, therefore, we shall ever be so fortunate as to discover the law of variation of that force which connects one atom of matter with another atom, and which is therefore characteristic of matter, and the ultimate source of all its sensible qualities, the curve whose ordinates represent the kind and the intensity of this atomical force will be something like that sketched in fig. 2. The first branch *an* B will have

Fig. 2.



AK (perpendicular to the axis AH) for its asymptote, and the last branch *lmo* will be to all sense a hyperbola, having AO for its asymptote; and the ordinates *IL*, *mM*, &c. will

be proportional to $\frac{1}{AL^2}$, $\frac{1}{AM^2}$, &c. expressing the universal

gravitation of matter. It will have many branches *BbC*, *DdE*, *FfG*, &c. expressing attractions, and alternate repulsive branches *CcD*, *EeF*, *GgH*, &c. All these will be contained within a distance AH, which does not exceed a very minute fraction of an inch.

The simplest particle which can be a constituent of a body having length, breadth, and thickness, must consist of four such atoms, all of which combine their influence on each atom of another such particle. It is evident that, the curve which expresses the force that connects two such particles must be totally different from this original curve, this hylarchic principle. Supposing the last known, our mathematical knowledge is quite able to discover the first; but when we proceed to compose a body of particles, each of

Strength of Materials. say that the compound force which connects them is almost beyond our search, and that the discovery of the primary force from an *accurate* knowledge of the corpuscular forces of *this* particular matter is absolutely out of our power.

All that we can learn is, the possibility, nay, the certainty, of an innumerable variety of external sensible forms and qualities, by which different kinds of matter will be distinguished, arising from the number, the order of composition, and the arrangement of the subordinate particles of which a particle of this or that kind of matter is composed. All these varieties will take place at those small and insensible distances which are between A and H, and may produce all that variety which we observe in the tangible or mechanical forms of bodies, such as elasticity, ductility, hardness, softness, fluidity, vapour, and all those unseen motions or actions which we observe in fusion and congelation, evaporation and condensation, solution and precipitation, crystallization, vegetable and animal assimilation and secretion, &c.; while all bodies must be, in a certain degree, elastic, all must gravitate, and all must be impenetrable.

The doctrine of cohesion yet a new subject.

This general and satisfactory resemblance between the appearance of tangible matter and the legitimate consequence of this general hypothetical property of an atom of matter, affords a considerable probability that such is the origin of all the phenomena. We earnestly recommend to our readers a careful perusal of Boscovich's celebrated treatise. A careful perusal is necessary for seeing its value; and nothing will be got by a hasty inspection. The reader will be particularly pleased with the facility and evidence with which the ingenious author has deduced all the ordinary principles of mechanics, and with the explanation which he has given of fluidity, and his deduction from thence of the laws of hydrostatics. No part of the treatise is more valuable than the doctrine of the propagation of pressure through solid bodies. This, however, is but just touched on in the course of the investigation of the principles of mechanics. We shall borrow as much as will suffice for our present inquiry into the strength of materials; and we trust that our readers are not displeased with this general sketch of the doctrine (if it may be so called) of the cohesion of bodies. It is curious and important in itself, and is the foundation of all the knowledge which we can acquire of the present article. We are sorry to say that it is as yet a new subject of study; but it is a very promising one, and we by no means despair of seeing the whole of chemistry brought by its means within the pale of mechanical science. The great and distinguishing agent in chemistry is heat, or fire the cause of heat; and one of its most singular effects is the conversion of bodies into elastic vapour. We have the clearest evidence that this is brought about by mechanical forces; for it can be opposed or prevented by external pressure, a very familiar mechanical force. We may perhaps find another mechanical force which will prevent fusion.

Having now made our readers familiar with the mode of action in which cohesion operates in giving strength to solid bodies, we proceed to consider the strains to which this strength is opposed.

Strains to which strength is opposed.

A piece of solid matter is exposed to four kinds of strains, different in the manner of their operation.

1. It may be torn asunder, as in the case of ropes, stretchers, king-posts, tie-beams, &c.
2. It may be crushed, as in the case of pillars, posts, and truss-beams.
3. It may be broken across, as happens to a joist or lever of any kind.
4. It may be wrenched or twisted, as in the case of the axle of a wheel, the nail of a press, &c.

1.—IT MAY BE PULLED ASUNDER.

This is the simplest of all strains, and the others are indeed modifications of it. To this the force of cohesion is *directly* opposed, with very little modification of its action by any particular circumstances.

When a long cylindrical or prismatic body, such as a rod of wood or metal, or a rope, is drawn by one end, it must be resisted at the other, in order to bring its cohesion into action. When it is fastened at one end, we cannot conceive it any other way than as equally stretched in all its parts; for all our observations and experiments on natural bodies concur in showing us that the forces which connect their particles in any way whatever are equal and opposite. This is called the *third law of motion*; and we admit its universality, while we affirm that it is purely experimental. Yet we have met with dissertations by persons of eminent knowledge, where propositions are maintained inconsistent with this. During the dispute about the communication of motion, some of the ablest writers have said, that a spring compressed or stretched at the two ends was gradually less and less compressed or stretched from the extremities towards the middle: but the same writers acknowledged the universal equality of action and re-action, which is quite incompatible with this state of the spring. No such inequality of compression or dilatation has ever been observed; and a little reflection will show it to be impossible, in consistency with the equality of action and re-action.

Since all parts are thus equally stretched, it follows that the strain in any transverse section is the same, as also in every point of that section. If therefore the body be supposed of a homogeneous texture, the cohesion of the parts is equable; and since every part is equally stretched, the particles are drawn to equal distances from their quiescent positions, and the forces which are thus excited, and now exerted in opposition to the straining force, are equal. This external force may be increased by degrees, which will gradually separate the parts of the body more and more from each other, and the connecting forces increase with this increase of distance, till at last the cohesion of some particles is overcome. This must be immediately followed by a rupture, because the remaining forces are now weaker than before.

It is the united force of cohesion, immediately before the disunion of the first particles, that we call the *strength* of the section. It may also be properly called its *absolute strength*, being exerted in the simplest form, and not modified by any relation to other circumstances.

If the external force have not produced any permanent change on the body, and it therefore recovers its former dimensions when the force is withdrawn, it is plain that this strain may be repeated as often as we please, and the body which withstands it once will always withstand it. It is evident that this should be attended to in all constructions, and that in all our investigations on this subject this should be kept strictly in view. When we treat a piece of soft clay in this manner, and with this precaution, the force employed must be very small. If we exceed this, we produce a permanent change. The rod of clay is not indeed torn asunder, but it has become somewhat more slender; the number of particles in a cross section is now smaller; and therefore, although it will again, in this new form, suffer or allow an endless repetition of a *certain* strain without any farther permanent change, this strain is smaller than the former.

Something of the same kind happens in all bodies which receive a *set* by the strain to which they are exposed. All ductile bodies are of this kind. But there are many bodies which are not ductile. Such bodies break completely whenever they are stretched beyond the limit of their perfect elasticity. Bodies of a fibrous structure exhibit very great

Strength of Materials.

Matter may be pulled asunder;

a circumstance to be attended to in every construction requiring strength.

Strength of Materials. Great varieties in cohesion, but

varieties in their cohesion. In some the fibres have no lateral cohesion, as in the case of a rope. The only way in which all the fibres can be made to unite their strength, is to twist them together. This causes them to bind each other so fast, that any one of them will break before it can be drawn out of the bundle. In other fibrous bodies, such as timber, the fibres are held together by some cement or gluten. This is seldom as strong as the fibre. Accordingly timber is much easier pulled asunder in a direction transverse to the fibres. There is, however, every possible variety in this particular.

In stretching and breaking fibrous bodies, the visible extension is frequently very considerable. This is not solely the increasing of the distance of the particles of the cohering fibre; the greatest part chiefly arises from drawing the crooked fibre straight. In this, too, there is great diversity; and it is accompanied with important differences in their power of withstanding a strain. In some woods, such as fir, the fibres on which the strength most depends are very straight. Such woods are commonly very elastic, do not take a set, and break abruptly when overstrained: others, such as oak and birch, have their resisting fibres very undulating and crooked, and stretch very sensibly by a strain. They are very liable to take a set, and they do not break so suddenly, but give warning by *complaining*, as the carpenters call it; that is, by giving visible signs of a derangement of texture. Hard bodies of an uniform glassy structure, or granulated like stones, are elastic through the whole extent of their cohesion, and take no set, but break at once when overloaded.

Notwithstanding the immense variety which nature exhibits in the structure and cohesion of bodies, there are certain general facts of which we may now avail ourselves with advantage. In particular,

the absolute cohesion or strength proportional to the area of the section perpendicular to the extending force.

The absolute cohesion is proportional to the area of the section. This must be the case where the texture is perfectly uniform, as we have reason to think it is in glass and the ductile metals. The cohesion of each particle being alike, the whole cohesion must be proportional to their number, that is, to the area of the section. The same must be admitted with respect to bodies of a granulated texture, where the granulation is regular and uniform. The same must be admitted of fibrous bodies, if we suppose their fibres equally strong, equally dense, and similarly disposed through the whole section; and this we must either suppose, or must state the diversity, and measure the cohesion accordingly.

We may therefore assert, as a general proposition on this subject, that the absolute strength in any part of a body, by which it resists being pulled asunder, or the force which must be employed to tear it asunder *in that part*, is proportional to the area of the section perpendicular to the extending force.

Therefore all cylindrical or prismatic rods are equally strong in every part, and will break alike in any part; and bodies which have unequal sections will always break in the slenderest part. The length of the cylinder or prism has no effect on the strength. Also the absolute strengths of bodies which have similar sections are proportional to the squares of their diameters or homologous sides of the section.

The weight of the body itself may be employed to strain it and to break it. It is evident, that a rope may be so long as to break by its own weight. When the rope is hanging perpendicularly, although it is equally strong in every part, it will break towards the upper end, because the strain on any part is the weight of all that is below it. Its *relative strength* in any part, or power of withstanding the strain

which is actually laid on it, is inversely as the quantity below that part.

Strength of Materials.

When the rope is stretched horizontally, as in towing a ship, the strain arising from its weight often bears a very sensible proportion to its whole strength.

These are the chief general rules which can be safely deduced from our clearest notions of the cohesion of bodies. In order to make any practical use of them, it is proper to have some measures of the cohesion of such bodies as are commonly employed in our mechanics, and other structures where they are exposed to this kind of strain. These must be deduced solely from experiment; therefore they must be considered as no more than general values, or as the averages of many particular trials. The irregularities are very great, because none of the substances are constant in their texture and firmness. Metals differ by a thousand circumstances unknown to us, according to their purity, to the heat with which they were melted, to the moulds in which they were cast, and the treatment they have afterwards received, by forging, wire-drawing, tempering, &c.

It is a very curious and inexplicable fact, that by forging a metal, or by frequently drawing it through a smooth hole in a steel plate, its cohesion is greatly increased. This operation undoubtedly deranges the natural situation of the particles. They are squeezed closer together in one direction, but it is not in the direction in which they resist the fracture. In this direction they are rather separated to a greater distance. The general density, however, is augmented in all of them except lead, which grows rather rarer by wire-drawing; but its cohesion may be more than tripled by this operation. Gold, silver, and brass, have their cohesion nearly tripled; copper and iron have it more than doubled. In this operation they also grow much harder. It is proper to heat them to redness after drawing a little. This is called *nealing* or *annealing*. It softens the metal again, and renders it susceptible of another drawing without the risk of cracking in the operation.

We do not pretend to give any explanation of this remarkable and very important fact, which has something resembling it in woods and other fibrous bodies, as will be mentioned afterwards.

The varieties in the cohesion of stones and other minerals, and of vegetable and animal substances, are hardly susceptible of any description or classification.

We shall take for the measure of cohesion the number of pounds avoirdupois which are just sufficient to tear asunder a rod or bundle of one inch square. From this it will be easy to compute the strength corresponding to any other dimension.

Cohesion and strength of different metals.

1st, Metals.		lbs.
Gold, cast.		{ 20,000
		{ 24,000
Silver, cast.		{ 40,000
		{ 43,000
Copper, cast,	Japan.....	19,000
	Barbary.....	22,000
	Hungary.....	31,000
	Anglesea... ..	34,000
	Sweden.....	37,000
Iron, cast.....		{ 42,000
		{ 59,000
Iron, bar.....	Ordinary.....	68,000
	Stirian.....	75,000
	Best Swedish and Russian.....	84,000
	Horse-nails.....	71,000 ¹

Relative strength.

¹ This was an experiment by Muschenbroeck, to examine the vulgar notion that iron forged from old horse-nails was stronger than all others, and shows its falsity.

Strength of
Materials.

Steel, bar	Soft.....	120,000
	Razor temper.....	150,000
Tin, cast.	Malacca.....	3,100
	Banca.....	3,600
	Block.....	3,800
	English block.....	5,200
	grain.....	6,500
Lead, cast.....		860
Regulus of antimony.....		1,000
Zinc.....		2,600
Bismuth.....		2,900

Tenacity
of metals
increased
by mix-
tures.

It is very remarkable, that almost all the mixtures of metals are more tenacious than the metals themselves. The change of tenacity depends much on the proportion of the ingredients, and the proportion which produces the most tenacious mixture is different in the different metals. We have selected the following from the experiments of Muschenbroeck. The proportion of ingredients here selected is that which produces the greatest strength.

Two parts of gold with one of silver.....	28,000
Five parts of gold with one of copper.....	50,000
Five parts of silver with one of copper.....	48,500
Four parts of silver with one of tin.....	41,000
Six parts of copper with one of tin.....	41,000
Five parts of Japan copper with one of Banca tin.....	57,000
Six parts of Chili copper with one of Malacca tin.....	60,000
Six parts of Swedish copper with one of Malacca tin.....	64,000
Brass consists of copper and zinc in an unknown proportion; its strength is.....	51,000
Three parts of block-tin with one part of lead.....	10,200
Eight parts of block-tin with one part of zinc.....	10,000
Four parts of Malacca tin with one part of regulus of antimony.....	12,000
Eight parts of lead with one of zinc.....	4,500
Four parts of tin with one of lead and one of zinc.....	13,000

These numbers are of considerable use in the arts. The mixtures of copper and tin are particularly interesting in the fabric of great guns. We see that, by mixing copper, whose greatest strength does not exceed 37,000, with tin, which does not exceed 6000, we produce a metal whose tenacity is almost double, at the same time that it is harder and more easily wrought. It is, however, more fusible, which is a great inconvenience. We also see that a very small addition of zinc almost doubles the tenacity of tin, and increases the tenacity of lead five times; and a small addition of lead doubles the tenacity of tin. These are economical mixtures. This is very valuable information to the plumbers, for augmenting the strength of water-pipes.

By having recourse to these tables, the engineer can proportion the thickness of his pipes, of whatever metal, to the pressures to which they are exposed.

2d, Woods.

We may premise to this part of the table the following general observations.

Tenacity
or strength
of wood.

1. The wood immediately surrounding the pith or heart of the tree is the weakest, and its inferiority is so much more remarkable as the tree is older. In this assertion, however, we speak with some hesitation. Muschenbroeck's detail of experiments is decidedly in the affirmative. M. Buffon, on the other hand, says that his experience has taught him that the heart of a sound tree is the strongest; but he gives no instances. From many observations of our own on very large oaks and firs, we are certain that the heart is much weaker than the exterior parts.

2. The wood next the bark, commonly called the *white* or *blea*, is also weaker than the rest; and the wood gradually increases in strength as we recede from the centre to the blea.

3. The wood is stronger in the middle of the trunk than

at the springing of the branches or at the root; and the wood of the branches is weaker than that of the trunk.

Strength of
Materials.

4. The wood of the north side of all trees which grow in our European climates is the weakest, and that of the south-east side is the strongest; and the difference is most remarkable in hedge-row trees, and such as grow singly. The heart of a tree is never in its centre, but always nearer to the north side, and the annual coats of wood are thinner on that side. In conformity with this, it is a general opinion of carpenters that timber is stronger whose annual plates are thicker. The trachea or air-vessels are weaker than the simple ligneous fibres. The air-vessels are the same in diameter and number of rows in trees of the same species, and they make the visible separation between the annual plates. Therefore, when these are thicker, they contain a greater proportion of the simple ligneous fibres.

5. All woods are more tenacious while green, and lose very considerably by drying after the trees are felled.

The only author who has put it in our power to judge of the propriety of his experiments is Muschenbroeck. He has described his method of trial minutely, and it seems unexceptionable. The woods were all formed into slips fit for his apparatus, and part of the slip was cut away to a parallelopiped of $\frac{1}{3}$ th of an inch square, and therefore $\frac{1}{27}$ th of a square inch in section. The absolute strengths of a square inch were as follow:

	lib.		lib.	
Locust tree.....	20,100	Pomegranate.....	9750	Absolute strength of different kinds of wood,
Juleb.....	18,500	Lemon.....	9250	
Beech, oak.....	17,300	Tamarind.....	8750	
Orange.....	15,500	Fir.....	8330	
Alder.....	13,900	Walnut.....	8130	
Elm.....	13,200	Pitch-pine.....	7650	
Mulberry.....	12,500	Quince.....	6750	
Willow.....	12,500	Cypress.....	6000	
Ash.....	12,000	Poplar.....	5500	
Plum.....	11,800	Cedar.....	4880	
Elder.....	10,000			

Muschenbroeck has given a very minute detail of the experiments on the ash and the walnut, stating the weights which were required to tear asunder slips taken from the four sides of the tree, and on each side, in a regular progression from the centre to the circumference. The number of this table corresponding to these two timbers may therefore be considered as the average of more than fifty trials made of each; and he says that all the others were made with the same care. We cannot therefore see any reason for not confiding in the results; yet they are considerably higher than those given by some other writers. Mr Pitot, on the authority of his own experiments, and of those of Mr Parent, avers that sixty pounds will just tear asunder a square line of sound oak, and that it will bear fifty with safety. This gives 8640 for the utmost strength of a square inch, which is much inferior to Muschenbroeck's valuation.

We may add to these,

Ivory.....	16,270	and of other substances.
Bone.....	5,250	
Horn.....	8,750	
Whalebone.....	7,500	
Tooth of sea-calf.....	4,075	

The reader will surely observe, that these numbers express something more than the utmost cohesion; for the weights are such as will very quickly, that is, in a minute or two, tear the rods asunder. It may be said in general, that two thirds of these weights will sensibly impair the strength after a considerable while, and that one half is the utmost that can remain suspended at them without risk for ever; and it is upon this last allotment that the engineer should reckon in his constructions. There is, however, considerable difference in this respect. Woods of a very straight

No substance to be strained in architecture above one half its strength.

Strength of fibre, such as fir, will be less impaired by any load which is not sufficient to break them immediately.

According to Mr Emerson, the load which may be safely suspended to an inch square is as follows :

Iron.....	76,400
Brass.....	35,600
Hemp rope.....	19,600
Ivory.....	15,700
Oak, box, yew, plum-tree.....	7,850
Elm, ash, beech,.....	6,070
Walnut, plum.....	5,360
Red fir, holly, elder, plane, crab.....	5,000
Cherry, hazel.....	4,760
Alder, asp, birch, willow.....	4,290
Lead.....	430
Freestone.....	914

He gives us a practical rule, that a cylinder whose diameter is d inches, loaded to one fourth of its absolute strength, will carry as follows :

Iron.....	135	} cwt.
Good rope.....	22	
Oak.....	14	
Fir.....	9	

The rank which the different woods hold in this list of Mr Emerson's is very different from what we find in Muschenbroeck's. But precise measures must not be expected in this matter. It is wonderful, that in a matter of such unquestionable importance the public has not enabled some persons of judgment to make proper trials. They are beyond the abilities of private persons.

II.—BODIES MAY BE CRUSHED.

It is of importance to know what will crush bodies.

It is of equal, perhaps greater, importance to know the strain which may be laid on solid bodies without danger of crushing them. Pillars and posts of all kinds are exposed to this strain in its simplest form ; and there are cases where the strain is enormous, viz. where it arises from the oblique position of the parts, as in the struts, braces, and trusses, which occur very frequently in our great works. It is therefore most desirable to have some general knowledge of the principle which determines the strength of bodies, in opposition to this kind of strain. But, unfortunately, we are much more at a loss in this than in the last case. The mechanism of nature is, in the present case, much more complicated. It must be in some circuitous way that compression can have any tendency to tear asunder the parts of a solid body, and it is very difficult to trace the steps.

If we suppose the particles insuperably hard and in contact, and disposed in lines which are in the direction of the external pressures, it does not appear how any pressure can disunite the particles ; but this is a gratuitous supposition. There are infinite odds against this precise arrangement of the lines of particles ; and the compressibility of all kinds of matter in some degree shows that the particles are in a situation equivalent to distance. This being the case, and the particles, with their intervals, or what is equivalent to intervals, being in situations that are oblique with respect to the pressures, it must follow, that by squeezing them together in one direction, they are made to bulge out or separate in other directions. This may proceed so far that some may be thus pushed laterally beyond their limits of cohesion. The moment that this happens the resistance to compression is diminished, and the body will now be crushed together. We may form some notion of this by supposing a number of spherules, like small shot, sticking together by means of a cement. Compressing this in some particular direction causes the spherules to act among each other like so many wedges, each tending to penetrate through between the three which lie below it : and this is the simplest, and perhaps the only distinct, notion we can have of the matter.

We have reason to think that the constitution of very homogeneous bodies, such as glass, is not very different from this.

If this be the constitution of bodies, it appears probable that the strength, or the resistance which they are capable of making to an attempt to crush them to pieces, is proportional to the area of the section whose plane is perpendicular to the external force ; for each particle being similarly and equally acted on and resisted, the whole resistance must be as their number, that is, as the extent of the section.

Accordingly this principle is assumed by the few writers who have considered the subject ; but we confess that it appears to us very doubtful. Suppose a number of brittle or friable balls lying on a table uniformly arranged, but not cohering nor in contact, and that a board is laid over them and loaded with a weight ; we have no hesitation in saying that the weight necessary to crush the whole collection is proportional to their number or to the area of the section. But when they are in contact, and still more if they cohere, we imagine that the case is materially altered. Any individual ball is crushed only in consequence of its being bulged outwards in the direction perpendicular to the pressure employed. If this could be prevented by a hoop put round the ball like an equator, we cannot see how any force can crush it. Any thing therefore which makes this bulging outwards more difficult, makes a greater force necessary. Now this effect will be produced by the mere contact of the balls before the pressure is applied ; for the central ball cannot swell outward laterally without pushing away the balls on all sides of it. This is prevented by the friction on the table and upper board, which is at least equal to one third of the pressure. Thus any interior ball becomes stronger by the mere vicinity of the others ; and if we further suppose them to cohere laterally, we think that its strength will be still more increased.

The analogy between these balls and the cohering particles of a friable body is very perfect. We should therefore expect that the strength by which it resists being crushed will increase in a greater ratio than that of the section, or the square of the diameter of similar sections ; and that a square inch of any matter will bear a greater weight in proportion as it makes a part of a greater section. Accordingly this appears in many experiments, as will afterwards be noticed. Muschenbroeck, Euler, and some others, have supposed the strength of columns to be as the biquadrates of their diameters. Euler deduced this from formulæ which occurred to him in the course of his algebraic analysis ; and he boldly adopts it as a principle, without looking for its foundation in the physical assumptions which he had made in the beginning of his investigation. But some of his original assumptions were as paradoxical, or at least as gratuitous, as these results ; and those, in particular, from which this proportion of the strength of columns was deduced, were almost foreign to the case ; and therefore the inference was of no value. Yet it was received as a principle by Muschenbroeck and by the academicians of St Petersburg. We make these very few observations, because the subject is of great practical importance ; and it is a great obstacle to improvements when deference to a great name, joined to incapacity or indolence, causes authors to adopt his careless reveries as principles from which they are afterwards to draw important consequences. It must be acknowledged that we have not as yet established, on solid mechanical principles, the relation between the dimensions and the strength of a pillar. Experience plainly contradicts the general opinion, that the strength is proportional to the area of the section ; but it is still more inconsistent with the opinion, that it is in the quadruplicate ratio of the diameters of similar sections. It would seem that the ratio depends much on the internal structure of the body ; and experiment seems the only method for ascertaining its general laws.

Strength of Materials. If we suppose the body to be of a fibrous texture, having the fibres situated in the direction of the pressure, and slightly adhering to each other by some kind of cement, such a body will fail only by the bending of the fibres, by which they will break the cement and be detached from each other. Something like this may be supposed in wooden pillars. In such cases, too, it would appear that the resistance must be as the number of equally resisting fibres, and as their mutual support, jointly; and, therefore, as some function of the area of the section. The same thing must happen if the fibres be naturally crooked or undulated, as is observed in many woods, provided we suppose some similarity in their form. Similarity of some kind must always be supposed, otherwise we need never aim at any general inferences.

In all cases therefore we can hardly refuse admitting that the strength in opposition to compression is proportional to a function of the area of the section.

As the whole length of a cylinder or prism is equally pressed, it does not appear that the strength of a pillar is at all affected by its length. If indeed it be supposed to bend under the pressure, the case is greatly changed, because it is then exposed to a transverse strain; and this increases with the length of the pillar. But this will be considered with due attention under the next class of strains.

Few experiments have been made on this species of strength and strain. Mr Pitot says that his experiments and those of Mr Parent show that the force necessary for crushing a body is nearly equal to that which will tear it asunder. He says that it requires something more than sixty pounds on every square line to crush a piece of sound oak. But the rule is by no means general: glass, for instance, will carry a hundred times as much as oak in this way, that is, resting on it; but will not *suspend* four or five times as much. Oak will suspend a great deal more than fir; but fir, as a pillar, will carry twice as much. Woods of a soft texture, although consisting of very tenacious fibres, are more easily crushed by their load. This softness of texture is chiefly owing to their fibres not being straight but undulated, and there being considerable vacuities between them, so that they are easily bent laterally and crushed. When a post is overstrained by its load, it is observed to swell sensibly in diameter. Increasing the load causes longitudinal cracks or shivers to appear, and it presently after gives way. This is called *crippling*.

In all cases where the fibres lie oblique to the strain, the strength is greatly diminished, because the parts can then be made to slide on each other when the cohesion of the cementing matter is overcome.

Muschenbroeck has given some experiments on this subject; but they are cases of long pillars, and therefore do not belong to this place. They will be considered afterwards.

The only experiments of which we have seen any detail (and it is useless to insert mere assertions) are those of Mr Gauthey, in the fourth volume of Rozier's *Journal de Physique*. This engineer exposed to great pressures small rectangular parallelipeds, cut from a great variety of stones, and noted the weights which crushed them. The following table exhibits the medium results of many trials on two very uniform kinds of freestone, one of them among the hardest and the other among the softest used in building.

Column first expresses the length AB of the section, in French lines or 12ths of an inch; column second expresses the breadth BC; column third is the area of the section, in square lines; column fourth is the number of ounces required to crush the piece; column fifth is the weight which was then borne by each square line of the section; and column sixth is the round numbers to which Mr Gauthey imagines that those in column fifth approximate.

<i>Hard Stone.</i>						
	AB.	BC.	AB×BC.	Weight.	Force.	
1	8	8	64	736	11·5	12
2	8	12	96	2625	27·3	24
3	8	16	128	4496	35·1	36
<i>Soft Stone.</i>						
4	9	16	144	560	3·9	4·
5	9	18	162	848	5·3	4·5
6	18	18	324	2928	9·	9·
7	18	24	432	5296	12·2	12·

Strength of Materials.
Experiments for this purpose made on free-stone

Little can be deduced from these experiments: the first and third, compared with the fifth and sixth, should furnish similar results; for the first and fifth are respectively half of the third and sixth; but the third is three times stronger (that is, a line of the third) than the first, whereas the sixth is only twice as strong as the fifth.

It is evident, however, that the strength increases much faster than the area of the section, and that a square line can carry more and more weight, according as it makes a part of a larger and larger section. In this series of experiments on the soft stone, the individual strength of a square line seems to increase nearly in the proportion of the section of which it makes a part.

Mr Gauthey deduces, from the whole of his numerous experiments, that a pillar of hard stone of Givry, whose section is a square foot, will bear with perfect safety 664,000 pounds, and that its extreme strength is 871,000; and the smallest strength observed in any of his experiments was 460,000. The soft bed of Givry stone had for its smallest strength 187,000, for its greatest 311,000, and for its safe load 249,000. Good brick will carry with safety 320,000; chalk will carry only 9000. The boldest piece of architecture in this respect which he has seen is a pillar in the church of All-Saints at Angers. It is twenty-four feet long and eleven inches square, and is loaded with 60,000, which is not one seventh of what is necessary for crushing it.

We may observe here by the way, that Mr Gauthey's measure of the suspending strength of stone is vastly small in proportion to its power of supporting a load laid above it. He finds that a prism of the hard bed of Givry, of a foot section, is torn asunder by 4600 pounds; and if it be firmly fixed horizontally in a wall, it will be broken by a weight of 56,000 suspended a foot from the wall. If it rest on two props at a foot distance, it will be broken by 206,000 laid on its middle. These experiments agree so not satisfactory with each other, that little use can be made of them. The subject is of great importance, and well deserves the attention of the patriotic philosopher.

A set of good experiments would be very valuable, because it is against this kind of strain that we must guard by judicious construction in the most delicate and difficult problems which come through the hands of the civil and military engineer. The construction of stone arches, and the construction of great wooden bridges, and particularly the construction of the frames of carpentry called *centres* in the erection of stone bridges, are the most difficult jobs that occur. In the centres on which the arches of the bridge of Orleans were built, some of the pieces of oak were carrying upwards of two tons on every square inch of their scantling. All who saw it said that it was not able to carry the fourth part of the intended load. But the engineer understood the principles of his art, and ran the risk, and the result completely justified his confidence; for the centre did not complain in any part, only it was found too supple; so that it went out of shape while the haunches only of the arch were laid on it. The engineer corrected this by loading it at the crown, and thus kept it completely in shape during the progress of the work.

In the Memoirs of the Academy of St Petersburg for

Strength of
Materials.

1778, there is a dissertation by Euler on this subject, but particularly limited to the strain on columns, in which the bending is taken into the account. Mr Fuss has treated the same subject with relation to carpentry in a subsequent volume. But there is little in these papers besides a dry mathematical disquisition, proceeding on assumptions which (to speak favourably) are extremely gratuitous. The most important consequence of the compression is wholly overlooked, as we shall presently see. Our knowledge of the mechanism of cohesion is as yet far too imperfect to entitle us to a confident application of mathematics. Experiments should be multiplied.

How they
are to be
made use-
ful.

The only way in which we can hope to make these experiments useful, is to pay a careful attention to the *manner* in which the fracture is produced. By discovering the general resemblances in this particular, we advance a step in our power of introducing mathematical measurement. Thus, when a cubical piece of chalk is slowly crushed between the chaps of a vice, we see it uniformly split in a surface oblique to the pressure, and the two parts then slide along the surface of fracture. This should lead us to examine mathematically what relation there is between this surface of fracture and the necessary force; then we should endeavour to determine experimentally the position of this surface. Having discovered some general law or resemblance in this circumstance, we should try what mathematical hypothesis will agree with this. Having found one, we may then apply our simplest notions of cohesion, and compare the result of our computations with experiment.

III.—A BODY MAY BE BROKEN ACROSS.

It is of im-
portance
to know
what strain
will break
a body
transverse-
ly.

The most usual, and the greatest strain, to which materials are exposed, is that which tends to break them transversely. It is seldom, however, that this is done in a manner perfectly simple; for when a beam projects horizontally from a wall, and a weight is suspended from its extremity, the beam is commonly broken near the wall, and the intermediate part has performed the functions of a lever. It sometimes, though rarely, happens that the pin in the joint of a pair of pincers or scissors is cut through by the strain; and this is almost the only case of a simple transverse fracture. Being so rare, we may content ourselves with saying, that in this case the strength of the piece is proportional to the area of the section.

Experi-
ments
made to
ascertain
it.

Experiments were made for discovering the resistances made by bodies to this kind of strain in the following manner. Two iron bars were disposed horizontally at an inch distance; a third hung perpendicularly between them, being supported by a pin made of the substance to be examined. This pin was made of a prismatic form, so as to fit exactly the holes in the three bars, which were made very exact, and of the same size and shape. A scale was suspended at the lower end of the perpendicular bar, and loaded till it tore out that part of the pin which filled the middle hole. This weight was evidently the measure of the lateral cohesion of two sections. The side-bars were made to grasp the middle bar pretty strongly between them, that there might be no distance interposed between the opposite pressures. This would have combined the energy of a lever with the purely transverse pressure. For the same reason it was necessary that the internal parts of the holes should be no smaller than the edges. Great irregularities occurred in our first experiments from this cause, because the pins were somewhat tighter within than at the edges; but when this was corrected they were extremely regular. We employed three sets of holes, viz. a circle, a square (which was occasionally made a rectangle whose length was twice its breadth), and an equilateral triangle. We found in all our experiments the strength exactly proportional to the area of the section, and quite independent of its figure or position, and

we found it considerably above the direct cohesion; that is, it took considerably more than twice the force to tear out this middle piece that it did to tear the pin asunder by a direct pull. A piece of fine freestone required 205 pounds to pull it directly asunder, and 575 to break it in this way. The difference was very constant in any one substance, but varied from four thirds to six thirds in different kinds of matter, being smallest in bodies of a fibrous texture. But indeed we could not make the trial on any bodies of considerable cohesion, because they required such forces as our apparatus could not support. Chalk, clay baked in the sun, baked sugar, brick, and freestone, were the strongest that we could examine.

But the more common case, where the energy of a lever intervenes, demands a minute examination. (B. B. B.)

Let ABCD (fig. 3) be the longitudinal section of a beam

inserted into a wall at the end AD, and supporting a weight at the free end BC: it is required to find what tendency the weight will have to break the beam over at the section EF.

The weight at C will, in the first place, cause a tendency of the part EBCF to slide down on the surface EF, but the strength of the beam in resisting this kind of dislocation is much greater than its power of resisting common fracture: it is therefore unnecessary to examine this case.

The weight at C will cause the beam to bend; that is, it will distend the upper and compress the under part of the beam, and, acting at the extremity of the lever FC, its power of causing such compression and distention will be $W \times FC$. Since the weight at C acts in a vertical direction, it cannot tend either to lengthen or to shorten the beam, and thus the repulsion of the compressed part must be exactly equal to the attraction of the distended parts.

Let G be the neutral point, and draw through it the line fGe , contiguous to FGE; draw also Hh and Ii parallel to CD. The lines Ii , in the under side of the cross section, will represent the degrees of compression, and also (since within the limits of security the repulsion is proportional to the degree of compression) the force of repulsion, while the lines Hh on the upper side will serve to represent the attractions. The sum of all the lines on the upper side, that is, the wedge EGe , will thus represent the entire amount of attraction, while the wedge FGf will represent the total amount of repulsion. These two wedges, then, must be equal to each other; and this equality determines the position of the axis of flexure represented by the point G. In the case of a rectangular beam, G must clearly be in the middle of the line EF; but when the cross section of the beam is irregular, the position of the axis of flexure is not quite so easily found.

Let EF be the cross section of an irregular beam, and OH the axis of flexure, or the place where the beam is neither compressed nor distended. Then the wedges generated by turning the section EF upon OH as an axis must be equal to each other. This is always the case when OH passes through the centre of gravity of the cross section, and thus it follows that those points which are neither compressed nor distended are always ranged in a straight line drawn through the centre of gravity of the cross section.

Fig. 3.

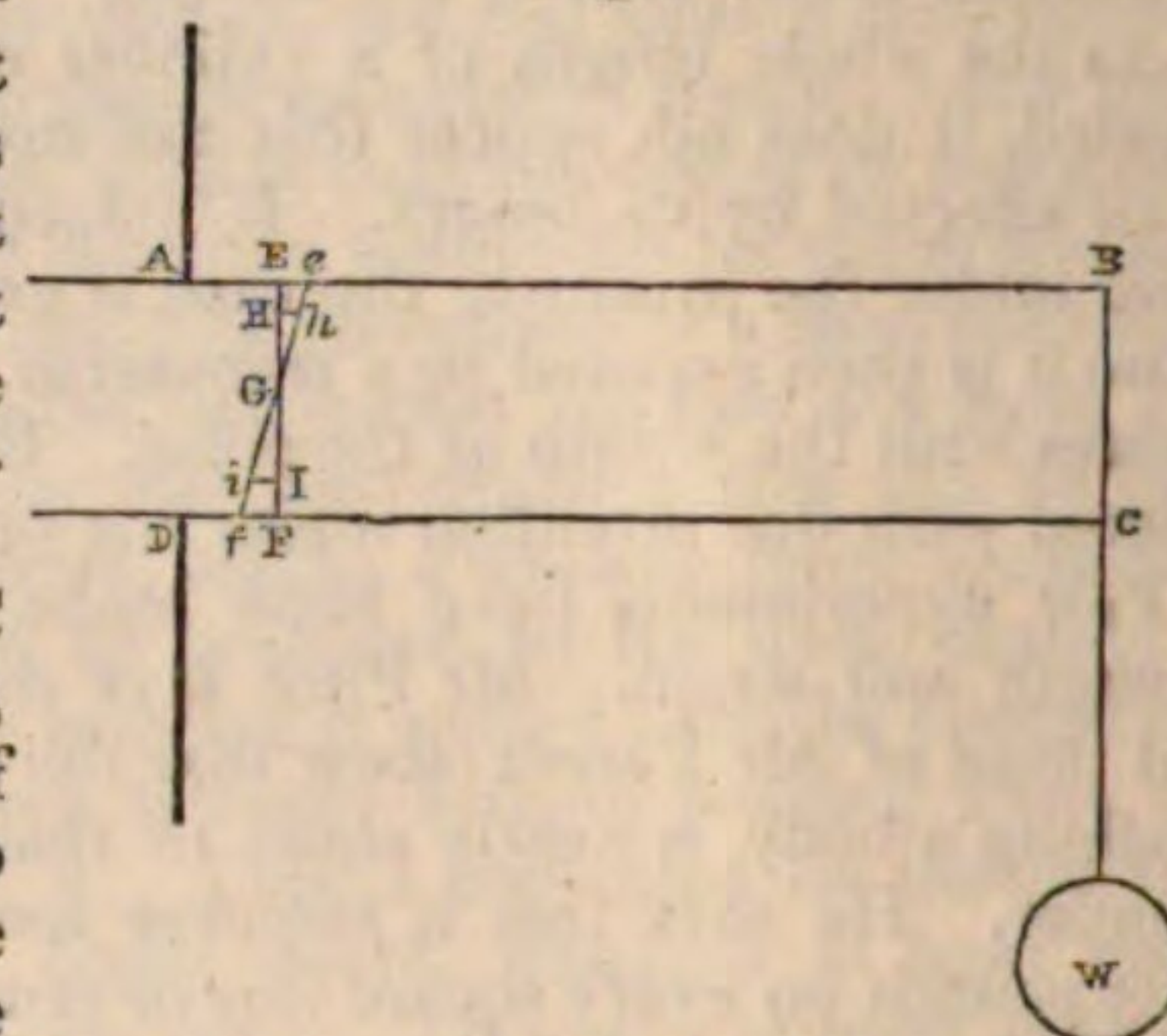
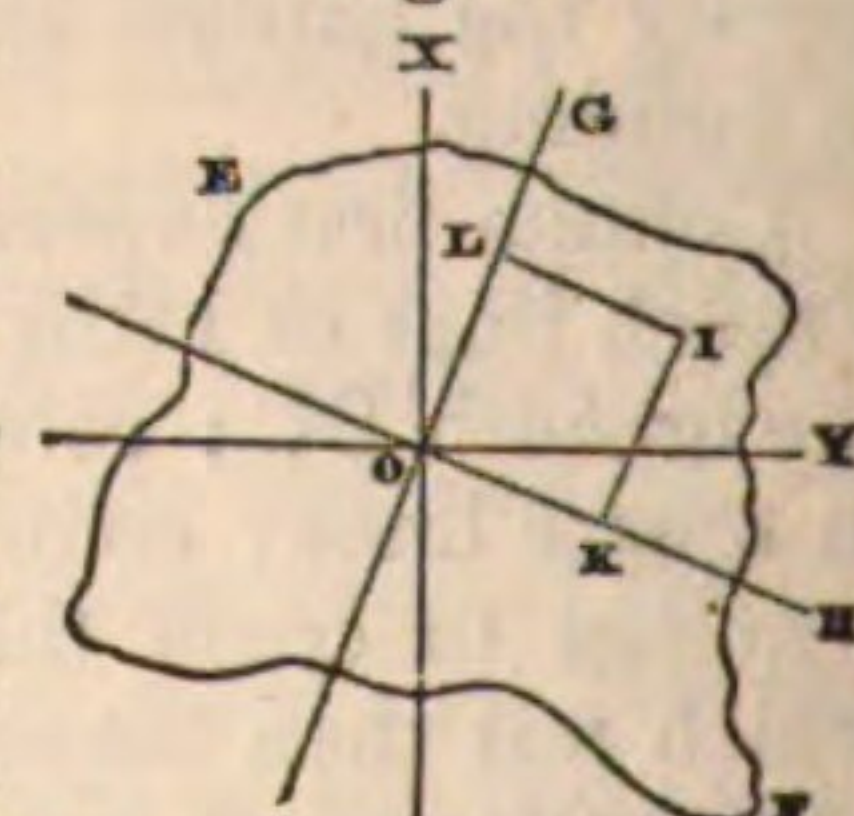


Fig. 4.



Strength of Materials. The position of the fulcrum of the lever being now known, we can proceed to ascertain the effects of the various forces.

Returning, for the sake of simplicity, to the rectangular beam; the sum of the repulsions iI will be represented by the triangle GfF : but the rectangle under GF and Ff would measure the entire strength of the under half of the beam, and therefore the force actually exerted when the beam is about to be broken across, is just half of the absolute strength of the beam; one quarter being exhibited as attraction, another quarter as repulsion. These forces act at different distances from the fulcrum G , and it is well known that the influence of a number of weights in turning a lever round is the same as if all these weights were to act at their common centre of gravity; so that to find the entire action in this case, we have to suppose one fourth of the whole strength of the beam to act at the distance $\frac{2}{3}$ of GF or $\frac{1}{3}$ of EF from the fulcrum G , and another quarter of the strength at $\frac{2}{3}$ of GE . Now, if s be the strength of one square inch of the beam, and if D , B , and L be its depth, breadth, and length, measured in inches, DBs will be the absolute strength of the whole beam; and therefore the tendencies of the above forces to straighten the beam will be

$$\frac{1}{4} DBs \times \frac{1}{3} D + \frac{1}{4} DBs \times \frac{1}{3} D;$$

that is, $\frac{1}{6} D^2 \cdot B \cdot s$. And again, the tendency of the weight W to bend the beam is WL ; so that

$$\frac{1}{6} D^2 \cdot B \cdot s = WL,$$

$$\text{or } 6L : D :: DBs : W;$$

that is, *as six times the length of the beam is to its depth, so is the absolute strength of the beam to the weight which it can carry at the free end.*

Throughout this investigation we have supposed that the force needed to extend or compress a fibre is exactly proportional to the quantity of extension or compression. This hypothesis, though not perhaps strictly true, and though it certainly errs when we approach to dislocation or fracture, is yet confirmed by all experiments when the extensions have been kept within the limits of safety: the results of this hypothesis therefore are what must guide us in forming any structure.

It may now be interesting to inquire into the strength of a beam when bent in different directions.

EF being, as before, the cross section of an irregular beam, let that beam be bent in the direction OG , the axis of flexure being OH perpendicular to OG ; and let us consider the action of a small portion ds of the surface situated at I . Having drawn the perpendiculars IK and IL , it is clear that the compression of the fibre I must be proportional to KI ; and therefore the force exerted by it may be denoted by $C \cdot IK \cdot ds$, C being some constant depending on the nature of the material and the degree of flexure. This force, conceived to act at the extremity of the lever KI , will tend to bend the beam round the axis OH ; but again acting at the end of the lever LI , it will tend to bend the beam on OG as an axis. Putting Σ to denote the integral for the entire surface, $C \cdot \Sigma \cdot IK^2 ds$ will be the entire tendency to rectify the form of the beam, and $C \Sigma IK \cdot IL \cdot ds$ will be the entire tendency to take a flexure in a plane at right angles to that which it actually has. A beam therefore will not bend in the direction in which the pressure is applied to it unless $\Sigma \cdot IK \cdot IL ds = 0$. This is a circumstance overlooked in all treatises on flexure; but it is one that must be carefully attended to in practice. It may easily be illustrated thus: Take a thin slip of wood, such perhaps as is used for Venetian blinds, and fix it in a vice so that while its length is horizontal its flat sides may be inclined at a considerable angle. Attach now a weight to the free end, and it will be found that that end does not descend vertically, but that it moves obliquely, the flexure not happening in that direction in which the force is applied. The force necessary to bend the beam in the plane of OG is not a force in that

direction, but is the resultant of two forces, $\Sigma IK^2 \cdot ds$ in the direction OG , and $\Sigma \cdot IK \cdot IL \cdot ds$ in the direction OH . For the present we shall call $\Sigma IK^2 ds$ the *stiffness in the direction* OG , and $\Sigma \cdot IL^2 ds$ of course the stiffness in the direction OH . The sum of these two stiffnesses is manifestly $\Sigma \cdot OI^2 ds$, which is a constant quantity, depending not at all upon the directions of OG , OH , but only on the form of the cross section: hence follows the remarkable law, that the sum of the stiffnesses of a beam in two directions perpendicular to each other is constant; and that therefore, whatever may be the form of the beam, its directions of greatest and least stiffness are always perpendicular to each other.

For the purpose of discovering in what directions the greatest and least stiffness lie, let us refer all the points in the cross section to the axes OX and OY , putting the angle $XOG = \phi$. We have then $IK = x \cos. \phi + y \sin. \phi$, $IL = -x \sin. \phi + y \cos. \phi$; and thus the tendency of the beam to redress itself in the direction GO is $\Sigma \cdot (x \cos. \phi + y \sin. \phi)^2 ds$, while the deflecting tendency in the direction HO is $\Sigma \cdot (x \cos. \phi + y \sin. \phi) (-x \sin. \phi + y \cos. \phi) ds$. Regarding ϕ as the variable quantity, and differentiating the former for the purpose of discovering its maximum, we obtain $\Sigma \cdot (x \cos. \phi + y \sin. \phi) (-x \sin. \phi + y \cos. \phi) ds = 0$; now it will be observed that this expression is just that for the deflecting tendency, and hence this law,

That when a beam is bent in the direction of greatest or of least stiffness, the pressure to be applied is exactly in the direction of the bending.

The value of ϕ may easily be found from the above equation; the result is

$$\tan. 2 \phi = \frac{2 \Sigma \cdot xy ds}{\Sigma x^2 ds - \Sigma y^2 ds}.$$

The lines OX and OY will coincide with the directions of greatest and least stiffness when $\phi = 0$, or when $\tan. 2 \phi = 0$, that is, when $\Sigma \cdot xy ds = 0$.

If, then, the directions of greatest and least stiffness be taken for the axes of xy and of y , we shall have $\Sigma \cdot xy ds = 0$, $\Sigma x^2 ds =$ greatest stiffness $= A$, $\Sigma y^2 ds =$ least stiffness $= B$. These being once known, the stiffness in any other direction, as well as the deflecting tendency, can readily be obtained. Putting P and Q respectively for these quantities, we have

$$P = A \cos. \phi^2 + B \sin. \phi^2,$$

$$Q = \frac{1}{2} (B - A) \sin. 2 \phi.$$

The deflecting tendency is thus greatest when $\phi = 45^\circ$, that is, when the actual direction of flexure is equally inclined to the directions of greatest and least stiffness. In this case

$$P^1 = \frac{1}{2} (A + B), \quad Q = \frac{1}{2} (B - A).$$

Galileo, who was the first to investigate the law of transverse strain, conceived the lower edge of the beam to be the fulcrum, and each fibre to be exerting its whole strength; Professor Robison, in the former editions of this work, corrected the supposition in the case of rectangular beams: the above investigation extends it to beams of all forms. (C. E.)

We must now remark, that this correction of the Galilean hypothesis of equal forces was suggested by the bending which is observed in all bodies which are strained transversely. Because they are bent, the fibres on the convex side have been extended. We cannot say in what proportion this obtains in the different fibres. Our most distinct notions of the internal equilibrium between the particles render it highly probable that their extension is proportional to their distance from that fibre which retains its former dimensions. But by whatever law this is regulated, we see plainly that the actions of the stretched fibres must follow the proportions of some function of this distance, and that therefore the relative strength of a beam is in all cases susceptible of mathematical determination.

Strength of
Materials.
Bernoulli's
problem of
the elastic
curve.

We also see an intimate connection between the strain and the curvature. This suggested to the celebrated James Bernoulli the problem of the *elastic curve*, i. e. the curve into which an extensible rigid body will be bent by a transverse strain. His solution in the *Acta Eruditorum* 1694 and 1695, is a very beautiful specimen of mathematical discussion, and we recommend it to the perusal of the curious reader. He will find it very perspicuously treated in the first volume of his works, published after his death, where the wide steps which he had taken in his investigation are explained so as to be easily comprehended. His nephew, Daniel Bernoulli, has given an elegant abridgement in the Petersburg Memoirs for 1729. The problem is too intricate to be fully discussed in a work like ours, but it is also too intimately connected with our present subject to be entirely omitted. We must content ourselves with showing the leading mechanical properties of this curve, from which the mathematician may deduce all its geometrical properties.

Its leading
mechanical
property
described.

When a bar of uniform depth and breadth, and of a given length, is bent into an arch of a circle, the extension of the outer fibres is proportional to the curvature; for, because the curves formed by the inner and outer sides of the beam are similar, the circumferences are as the radii, and the radius of the inner circle is to the difference of the radii as the length of the inner circumference is to the difference of the circumferences. The difference of the radii is the depth of the beam, the difference of the circumferences is the extension of the outer fibres, and the inner circumference is supposed to be the primitive length of the beam. Now the second and third quantities of the above analogy, viz. the depth and length of the beam, are constant quantities, as is also their product. Therefore the product of the inner radius and the extension of the outer fibre is also a constant quantity, and the whole extension of the outer fibre is inversely as the radius of curvature, or is directly as the curvature of the beam.

The mathematical reader will readily see, that into whatever curve the elastic bar is bent, the whole extension of the outer fibre is equal to the length of a similar curve having the same proportion to the thickness of the beam that the length of the beam has to the radius of curvature.

Now let ADCB (fig. 5) be such a rod of uniform breadth and thickness, firmly fixed in a vertical position, and bent into a curve AEFB by a weight W suspended at B, and of such magnitude that the extremity B has its tangent perpendicular to the action of the weight, or parallel to the horizon.

Suppose, too, that the extensions are proportional to the extending forces. From any two points E and F draw the horizontal ordinates EG, FH. It is evident that the exterior fibres of the sections Ee and Ff are stretched by forces which are in the proportion of EG to FH (these being the long arms of the levers, and the equal thicknesses Ee, Ff being the short arms). Therefore (by the hypothesis) their extensions are in the same proportion. But because the extensions are proportional to some similar functions of the distance from the axes of fracture E and F, the extension of any fibre in the section Ee is to the contemporaneous extension of the similarly situated fibre in the section Ff, as the extension of the exterior fibre in the section Ee is to the extension of the exterior fibre in the section Ff: therefore the whole extension of Ee is to the whole extension of Ff as EG to FH, and EG is to FH as the curvature in E to the curvature in F.

Here let it be remarked, that this proportionality of the curvature to the extension of the fibres is not limited to the

hypothesis of the proportionality of the extensions to the extending forces: it follows from the extension in the different sections being as some similar function of the distance from the axis of fracture; an assumption which cannot be refused.

This, then, is the fundamental property of the elastic curve, from which its equation, or relation between the abscissa and ordinate, may be deduced in the usual forms, and all its other geometrical properties. These are foreign to our purpose; and we shall notice only such properties as have an immediate relation to the strain and strength of the different parts of a flexible body, and which in particular serve to explain some difficulties in the valuable experiments of Buffon on the Strength of Beams.

We observe, in the first place, that the elastic curve can- It is not a not be a circle, but is gradually more incurvated as it re- circle. cedes from the point of application B of the straining forces. At B it has no curvature; and if the bar were extended beyond B there would be no curvature there. In like manner, when a beam is supported at the ends and loaded in the middle, the curvature is greatest in the middle; but at the props, or beyond them, if the beam extend farther, there is no curvature. Therefore, when a beam projecting twenty feet from a wall is bent to a certain curvature at the wall by a weight suspended at the end, and a beam of the same size projecting twenty feet is bent to the very same curvature at the wall by a greater weight at ten feet distance, the figure and the mechanical state of the beam in the vicinity of the wall is different in these two cases, though the curvature at the very wall is the same in both. In the first case every part of the beam is incurvated; in the second, all beyond the ten feet is without curvature. In the first experiment the curvature at the distance of five feet from the wall is three fourths of the curvature at the wall; in the second, the curvature at the same place is but one half of that at the wall. This must weaken the long beam in this whole interval of five feet, because the greater curvature is the result of a greater extension of the fibres.

In the next place we may remark, that there is a certain Every beam determinate curvature for every beam, which cannot be ex- has a cer- ceeded without breaking it; for there is a certain separa- tain deter- tion of two adjoining particles that puts an end to their co- minate cur-hesion. A fibre can therefore be extended only a certain- vature. proportion of its length. The ultimate extension of the outer fibres must bear a certain determinate proportion to its length, and this proportion is the same with that of the thickness (or what we have hitherto called the depth) to the radius of ultimate curvature, which is therefore determinate.

A beam of uniform breadth and depth is therefore most And when incurvated where the strain is greatest, and will break in of uniform breadth and depth, is most incur- the most incurvated part. But by changing its form, so as vated to make the strength of its different sections in the ratio of where the strain is greatest. the strain, it is evident that the curvature may be the same throughout, or may be made to vary according to any law. This is a remark worthy of the attention of the watchmaker. The most delicate problem in practical mechanics is so to taper the balance-spring of a watch that its wide and narrow vibrations may be isochronous. Hooke's principle *ut tensio sic vis* is not sufficient when we take the inertia and motion of the spring itself into the account. The figure into which it bends and unbends has also an influence. Our readers will take notice that the artist aims at an accuracy which will not admit an error of $\frac{1}{86400}$ th, and that Harrison and Arnold have actually attained it in several instances. The taper of a spring is at present a nostrum in the hands of each artist, and he is careful not to impart its secret.

Again, since the depth of the beam is thus proportional to the radius of ultimate curvature, this ultimate or breaking curvature is inversely as the depth. It may be expressed

by $\frac{1}{d}$.

Strength of
Materials.

To what
the curva-
ture is pro-
portional.

When a weight is hung on the end of a prismatic beam, the curvature is nearly as the weight and the length directly, and as the breadth and the cube of the depth in-

versely; for the strength is $= f \frac{bd^2}{6l}$. Let us suppose that this produces the ultimate curvature $\frac{1}{d}$. Now let the beam

be loaded with a smaller weight w , and let the curvature produced be C ; we have this analogy, $f \frac{bd^2}{6l} : w = \frac{1}{d} : C$, and

$C = \frac{6lw}{fbd^3}$. It is evident that this is also true of a beam

supported at the ends and loaded between the props; and we see how to determine the curvature in its different parts, whether arising from the load, or from its own weight, or from both.

Deflection.

When a beam is thus loaded at the end or middle, the loaded point is pulled down, and the space through which it is drawn may be called the *deflection*. This may be considered as the subtense of the angle of contact, or as the versed sine of the arch into which the beam is bent, and is therefore as the curvature when the length of the arches is given (the flexure being moderate), and as the square of the length of the arch when the curvature is given. The deflection therefore is as the curvature and as the square of

the length of the arch jointly; that is, as $\frac{6lw}{fbd^3} \times l^2$, or as

$\frac{6l^3w}{fbd^3}$. The deflection from the primitive shape is therefore as the bending weight and the cube of the length directly, and as the breadth and cube of the depth inversely.

In beams just ready to break, the curvature is as the depth inversely, and the deflection is as the square of the length divided by the depth; for the ultimate curvature at the breaking part is the same whatever is the length; and in this case the deflection is as the square of the length.

The theo-
rems result-
ing from
this subject
afford the
finest me-
thods of ex-
amining
the laws of
corpuseular
action.

We have been the more particular in our consideration of this subject, because the resulting theorems afford us the finest methods of examining the laws of corpuseular action, that is, for discovering the variation of the force of cohesion by a change of distance. It is true it is not the atomical law, or *hylarchic principle* as it may justly be called, which is thus made accessible, but the specific law of the particles of the substance or kind of matter under examination. But even this is a very great point; and coincidences in this respect among the different kinds of matter are of great moment. We may thus learn the nature of the corpuseular action of different substances, and perhaps approach to a discovery of the *mechanism* of chemical affinities. For that chemical actions are insensible cases of local motion is undeniable, and local motion is the province of mechanical discussion; nay, we see that these hidden changes are produced by mechanical forces in many important cases, for we see them promoted or prevented by means purely mechanical. The conversion of bodies into elastic vapour by heat can at all times be prevented by a *sufficient* external pressure. A strong solution of Glauber's salts will congeal in an instant by agitation, giving out its latent heat; and it will remain fluid for ever, and retain its latent heat in a close vessel which it completely fills. Even water will by such treatment freeze in an instant by agitation, or remain fluid for ever by confinement. We know that heat is produced or extricated by friction, that certain compounds of gold or silver with saline matters explode with irresistible violence by the smallest pressure or agitation. Such facts should rouse the mathematical philosopher, and excite him to follow out the conjectures of the illustrious Newton, encouraged by the ingenious attempts of Boscovich; and the proper beginning of this study is to at-

tend to the laws of attraction and repulsion exerted by the particles of cohering bodies, discoverable by experiments made on their actual extensions and compressions. The experiments of simple extensions and compressions are quite insufficient, because the total stretching of a wire is so small a quantity, that the mistake of the 1000th part of an inch occasions an irregularity which deranges any progression so as to make it useless. But by the bending of bodies a distention of $\frac{1}{100}$ th of an inch may be easily magnified in the deflection of the spring ten thousand times. We know that the investigation is intricate and difficult, but not beyond the reach of our present mathematical attainments; and it will give very fine opportunities of employing all the address of analysis. In the 17th century and the beginning of the 18th this was a sufficient excitement to the first geniuses of Europe. The cycloid, the catenaria, the elastic curve, the velaria, the caustics, were reckoned an abundant recompense for much study; and James Bernoulli requested, as an honourable monument, that the logarithmic spiral might be inscribed on his tombstone. The reward for the study to which we now presume to incite the mathematicians is the almost unlimited extension of natural science, important in every particular branch. To go no further than our present subject, a great deal of important practical knowledge respecting the strength of bodies is derived from the single observation, that in the moderate extensions which happen before the parts are overstrained, the forces are nearly in the proportion of the extensions or separations of the particles. To return to our subject.

James Bernoulli, in his second dissertation on the elastic curve, calls in question this law, and accommodates his investigation to any hypothesis concerning the relation of the forces and extensions. He relates some experiments of lute-strings where the relation was considerably different. Strings of three feet long,

stretched by 2, 4, 6, 8, 10 pounds,
were lengthened 9, 17, 23, 27, 30 lines.

But this is a most exceptionable form of the experiment. The strings were twisted, and the mechanism of the extensions is here exceedingly complicated, combined with compressions and with transverse twists, &c. We made experiments on fine slips of the gum caoutchouc, and on the juice of the berries of the white bryony, of which a single grain will draw to a thread of two feet long, and again return into a perfectly round sphere. We measured the diameter of the thread by a microscope with a micrometer, and thus could tell in every state of extension the proportional number of particles in the sections. We found, that through the whole range in which the distance of the particles was changed in the proportion of thirteen to one, the extensions did not *sensibly* deviate from the proportion of the forces. The same thing was observed in the caoutchouc as long as it perfectly recovered its first dimensions. And it is on the authority of these experiments that we presume to announce this as a law of nature.

Dr Robert Hooke was undoubtedly the first who attended to this subject, and assumed this as a law of nature. Mariotte indeed was the first who expressly used it for determining the strength of beams: this he did about the year 1679, correcting the simple theory of Galileo. Leibnitz, indeed, in his dissertation in the *Acta Eruditorum* 1684, *De Resistentia Solidorum*, introduces this consideration, and wishes to be considered as the discoverer; and he is always acknowledged as such by the Bernoullis, and others who adhered to his peculiar doctrines. But Mariotte had published the doctrine in the most express terms long before; and Bulfinger, in the *Comment. Petropol.* 1729, completely vindicates his claim. But Hooke was unquestionably the discoverer of this law. It made the foundation of his theory of springs, announced to the Royal Society about the year 1661, and read in 1666. On this occasion he mentions

Strength of
Materials.

calls in
question
this law,

which was
first assum-
ed by Dr
Hooke.

Strength of Materials. pose that the crooked lever virtually concerned in the strain is DAB. We must find the point I, which is the centre of effort of all the attractive forces, or that point where the full cohesion of AD must be applied, so as to have a momentum equal to the accumulated momenta of all the variable forces. We must in like manner find the centre of effort i of the repulsive or supporting forces exerted by the fibres lying between A and Δ .

It is plain, and the remark is important, that this last centre of effort is the real fulcrum of the lever, although A is the point where there is neither extension nor contraction; for the lever is supported in the same manner as if the repulsions of the whole line A Δ were exerted at that point. Therefore let S represent the surface of fracture from A to D, and f represent the absolute cohesion of a fibre at D in the instant of fracture. We shall have $fS \times I + i = pl$, or $l : I + i = fS : p$; that is, the length AB is to the distance between the two centres of effort I and i , as the absolute cohesion of the section between A and D is to the relative strength of the section.

It would be perhaps more accurate to make AI and Ai equal to the distances of A from the horizontal lines passing through the centres of gravity of the triangles of dAD and $\delta A\Delta$. It is only in this construction that the points I and i are the centres of real effort of the accumulated attractions and repulsions. But I and i , determined as we have done, are the points where the full equal actions may be all applied, so as to produce the same momenta. The final results are the same in both cases. The attentive and duly informed reader will see that Mr Bulfinger, in a very elaborate dissertation on the strength of beams, in the *Comment. Petropolitane*, 1729, has committed several mistakes in his estimation of the actions of the fibres. We mention this because his reasonings are quoted and appealed to as authorities by Muschenbroeck and other authors of note. The subject has been considered by many authors on the continent. We recommend to the reader's perusal the very minute discussions in the *Memoirs of the Academy of Paris* for 1702 by Varignon, the *Memoirs* for 1708 by Parent, and particularly that of Coulomb in the *Mém. par les Sçavans Etrangers*, tom. vii.

It is evident from what has been said above, that if S and s represent the surfaces of the sections above and below A, and if G and g are the distances of their centres of gravity from A, and O and o the distances of their centres of oscillation, and D and d their whole depths, the momentum of cohesion will be $\frac{fS \cdot G \cdot O}{D} = \frac{fs \cdot g \cdot o}{d} = pl$.

If, as is most likely, the forces are proportional to the extensions and compressions, the distances AI and Ai, which are respectively $\frac{G \cdot O}{D}$ and $\frac{g \cdot o}{d}$, are respectively $\frac{1}{3}DA$ and $\frac{1}{3}\Delta A$, and when taken together are $\frac{1}{3}D\Delta$. If, moreover, the extensions are equal to the compressions in the instant of fracture, and the body is a rectangular prism like a common joist or beam, then DA and ΔA are also equal; and therefore the momentum of cohesion is

$$fb \times \frac{1}{2}d \times \frac{1}{3}d = \frac{fbd^2}{6} = fbd \times \frac{1}{6}d = pl. \text{ Hence we}$$

obtain this analogy: "six times the length is to the depth as the absolute cohesion of the section is to its relative strength."

This consequence farther explained. Thus we see that the compressibility of bodies has a very great influence on their power of withstanding a transverse strain. We see that in this most favourable supposition of equal dilatations and compressions, the strength is reduced to one half of the value of what it would have been had the body been incompressible. This is by no means obvious; for it does not readily appear how compressibi-

lity, which does not diminish the cohesion of a single fibre, should impair the strength of the whole. The reason, however, is sufficiently convincing when pointed out. In the instant of fracture, a smaller portion of the section is actually exerting cohesive forces, while a part of it is only serving as a fulcrum to the lever by whose means the strain on the section is produced. We see, too, that this diminution of strength does not so much depend on the sensible compressibility, as on its proportion to the dilatability by equal forces. When this proportion is small, A Δ is small in comparison of AD, and a greater portion of the whole fibre is exerting attractive forces. The experiments already mentioned, of Duhamel de Monceau, on battens of willow, show that its compressibility is nearly equal to its dilatability. But the case is not very different in tempered steel. The famous Harrison, in the delicate experiments which he made while occupied in making his longitude watch, discovered that a rod of tempered steel was nearly as much diminished in its length as it was augmented by the same external force. But it is not by any means certain that this is the proportion of dilatation and compression which obtains in the very instant of fracture. We rather imagine that it is not. The forces are nearly as the dilatations till very near breaking; but we think that they diminish when the body is just going to break. But it seems certain that the forces which resist compression increase faster than the compressions, even before fracture. We know incontestably that the ultimate resistances to compression are insuperable by any force which we can employ. The repulsive forces, therefore, in their whole extent, increase faster than the compressions, and are expressed by an asymptotic branch of the Boscovician curve formerly explained. It is therefore probable, especially in the more simple substances, that they increase faster, even in such compressions as frequently obtain in the breaking of hard bodies. We are disposed to think that this is always the case in such bodies as do not fly off in splinters on the concave side; but this must be understood with the exception of the permanent changes which may be made by compression when the bodies are crippled by it. This always increases the compression itself, and causes the neutral point to shift still more towards D. The effect of this is sometimes very great and fatal.

Experiment alone can help us to discover the proportion between the dilatability and compressibility of bodies. The strain now under consideration seems the best calculated for this research. Thus if we find that a piece of wood an inch square requires 12,000 pounds to tear it asunder by a direct pull, and that 200 pounds will break it transversely by acting 10 inches from the section of fracture, we must conclude that the neutral point A is in the middle of the depth, and that the attractive and repulsive forces are equal. Any notions that we can form of the constitution of such fibrous bodies as timber, make us imagine that the sensible compressions, including what arises from the bending up of the compressed fibres, is much greater than the real corpuscular extensions. One may get a general conviction of this unexpected proposition by reflecting on what must happen during the fracture. An undulated fibre can only be drawn straight, and then the corpuscular extension begins; but it may be bent up by compression to any degree, the corpuscular compression being little affected all the while. This observation is very important; and though the forces of corpuscular repulsion may be almost insuperable by any compression that we can employ, a sensible compression may be produced by forces not enormous, sufficient to cripple the beam. Of this we shall see very important instances afterwards.

It deserves to be noticed, that although the relative strength of a prismatic solid is extremely different in the three hypotheses now considered, yet the proportional

Strength of Materials. The proportional strengths of different pieces follow the same ratio. The direct ratio of the breadth, the direct ratio of the square of the depth, and the inverse ratio of the length. In the first hypothesis (of equal forces) the strength of a rectangular beam was $\frac{fbd^2}{2l}$; in the second (of attractive forces proportioned to the extensions) it was $\frac{fbd^2}{3l}$; and in the third (equal attractions and repulsions proportional to the extensions and compressions) it was $\frac{fbd^2}{6l}$, or more generally $\frac{fbd^2}{ml}$, where m expresses the unknown proportion between the attractions and repulsions corresponding to an equal extension and compression.

Hence we derive a piece of useful information, which is confirmed by unexceptionable experience, that the strength of a piece depends chiefly on its depth, that is, on that dimension which is in the direction of the strain. A bar of timber of one inch in breadth and two inches in depth is four times as strong as a bar only one inch deep, and it is twice as strong as a bar two inches broad and one deep; that is, a joist or lever is always strongest when laid on its edge.

There is therefore a choice in the manner in which the cohesion is opposed to the strain. The general aim must be to put the centre of effort I as far from the fulcrum or the neutral point A as possible, so as to give the greatest energy or momentum to the cohesion. Thus if a triangular bar projecting from a wall is loaded with a weight at its extremity, it will bear thrice as much when one of the sides is uppermost as when it is undermost.

Hence it follows that the strongest joist that can be cut out of a round tree is not the one which has the greatest quantity of timber in it, but such that the product of its breadth by the square of its depth shall be the greatest possible. Let $ABCD$ (fig. 7) be the section of this joist inscribed in the circle, AB being the breadth and AD the depth. Since it is a rectangular section, the diagonal BD is a diameter of the circle, and BAD is a right-angled triangle. Let BD be called a , and BA be called x ; then $AD = \sqrt{a^2 - x^2}$. Now we must have $AB \cdot AD^2$, or $x(a^2 - x^2)$, or $a^2x - x^3$, a minimum; its differential $(a^2 - 3x^2)dx$ must be 0, or $a^2 = 3x^2$, or $x^2 = \frac{a^2}{3}$. If therefore we make $DE = \frac{1}{3}DB$, and draw EC perpendicular to BD , it will cut the circumference in the point C , which determines the depth BC and the breadth CD .

Because $BD : BC = CD : CE$, we have the area of the section $BC \cdot CD = BD \cdot CE$. Therefore the different sections having the same diagonal BD , are proportional to their heights CE . Therefore the section $BCDA$ is less than the section $Bc Da$, whose four sides are equal. The joist so shaped, therefore, is stronger, lighter, and cheaper.

The strength of $ABCD$ is to that of $a B c D$ as 10,000 to 9186, and the weight and expense as 10,000 to 10,607; so that $ABCD$ is preferable to $a B c D$, in the proportion of 10,607 to 9186, or nearly 115 to 100.

From the same principles it follows that a hollow tube is stronger than a solid rod containing the same quantity of matter. Let fig. 8 represent the section of a cylindric tube, of which AF and BE are the exterior and interior diameters, and C the centre. Draw BD perpendicular to BC , and join DC . Then, because $BD^2 = CD^2 - CB^2$, BD is the radius of a circle containing the same quantity of matter with the ring. If we estimate the strength by

A hollow tube stronger than a solid rod containing the same quantity of matter,

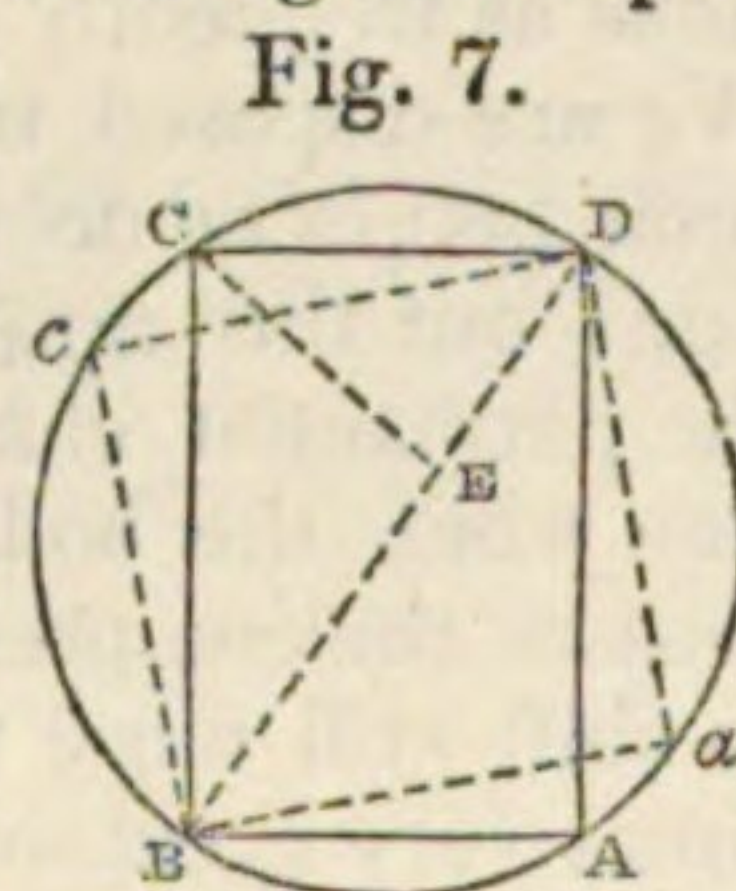


Fig. 7.

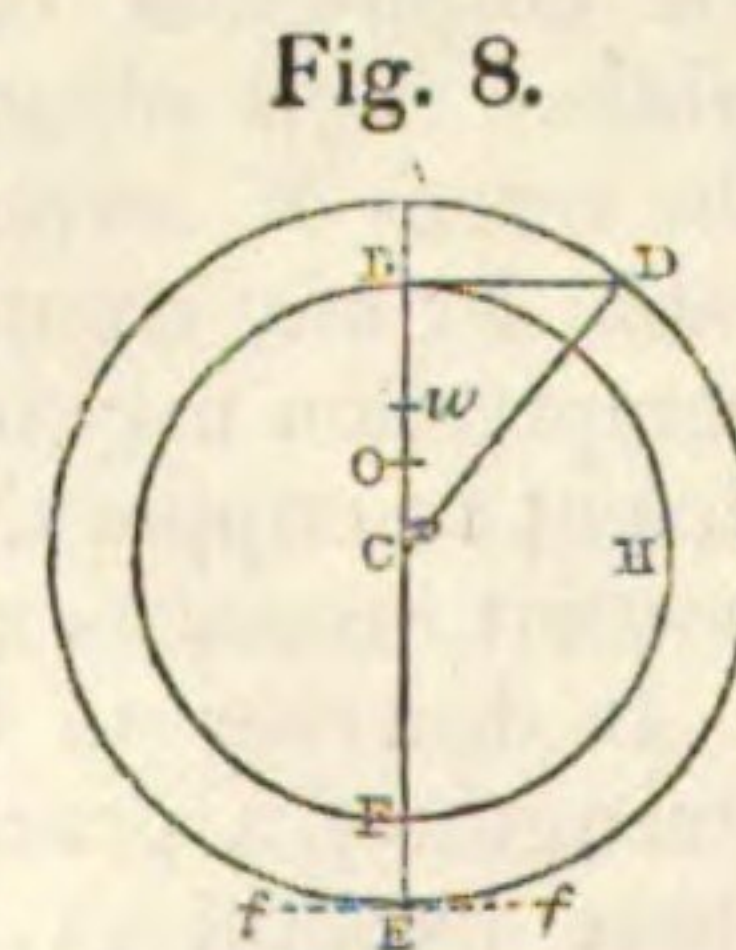


Fig. 8.

the first hypothesis, it is evident that the strength of the tube will be to that of the solid cylinder, whose radius is BD , as $BD^2 \times AC$ to $BD^2 \times BD$; that is, as AC to BD ; for BD^2 expresses the cohesion of the ring of the circle, and AC and BD are equal to distances of the centres of effort (the same with the centres of gravity) of the ring and circle from the axis of the fracture.

The proportion of these strengths will be different in the other hypothesis, and is not easily expressed by a general formula; but in both it is still more in favour of the ring or hollow tube.

The following very simple solution will be readily understood by the intelligent reader. Let O be the centre of oscillation of the exterior circle, o the centre of oscillation of the inner circle, and w the centre of oscillation of the ring included between them. Let M be the quantity of surface of the exterior circle, m that of the inner circle, and μ that of the ring.

$$\text{We have } Fw = \frac{M \cdot FO - m \cdot Fo}{\mu} = \frac{5 FC^2 + EC^2}{4 FC}, \text{ and}$$

the strength of the ring $= \frac{f \mu \times Fw}{2}$, and the strength of

the same quantity of matter in the form of a solid cylinder is $f \mu \times \frac{1}{8} BD$; so that the strength of the ring is to that of the solid rod of equal weight as Fw to $\frac{1}{8} BD$, or nearly as FC to BD . This will easily appear by recollecting that FO is

$$= \frac{\text{sum of } p \cdot r^2}{m \cdot FC} \text{ (see ROTATION), and that the momentum of}$$

$$\text{cohesion is } \frac{fm \cdot FC \cdot Ca}{2 FC} = \frac{fm \cdot Fo}{2} \text{ for the inner circle, \&c.}$$

Emerson has given a very inaccurate approximation to this value in his *Mechanics*, 4to.

This property of hollow tubes is accompanied also with greater stiffness; and the superiority in strength and stiffness is so much the greater as the surrounding shell is thinner in proportion to its diameter.

Here we see the admirable wisdom of the Author of nature in forming the bones of animal limbs hollow. The bones of the arms and legs have to perform the office of levers, and are thus opposed to very great transverse strains. By this form they become incomparably stronger and stiffer, and give more room for the insertion of muscles, while they are lighter and therefore more agile; and the same wisdom has made use of this hollow for other valuable purposes of the animal economy. In like manner the quills in the wings of birds acquire by their thinness the very great strength which is necessary, while they are so light as to give sufficient buoyancy to the animal in the rare medium in which it must live and fly about. The stalks of many plants, such as all the grasses, and many reeds, are in like manner hollow, and thus possess an extraordinary strength. Our best engineers now begin to imitate nature by making many parts of their machines hollow, such as their axles of cast iron, &c.; and the ingenious Mr Ramsden made the axes and framings of his great astronomical instruments in the same manner.

In the supposition of homogeneous texture, it is plain that the fracture happens as soon as the particles at D are separated beyond their utmost limit of cohesion. This is a determined quantity, and the piece bends till this degree of extension is produced in the uttermost fibre. It follows, that the smaller we suppose the distance between A and D , the greater will be the curvature which the beam will acquire before it breaks. Greater depth therefore makes a beam not only stronger, but also stiffer. But if the parallel fibres can slide on each other, both the strength and the stiffness will be diminished. Therefore, if, instead of one beam $D\Delta KC$ (fig. 6), we suppose two, $DABC$ and

Strength of Materials. ΔAKB , not cohering, each of them will bend, and the extension of the fibres AB of the under beam will not hinder the compression of the adjoining fibres AB of the upper beam. The two together therefore will not be more than twice as strong as one of them (supposing $DA = A\Delta$). instead of being four times as strong; and they will bend as much as either of them alone would bend by half the load. This may be prevented, if it were possible to unite the two beams all along the seam AB, so that the one shall not slide on the other. This may be done in small works by gluing them together with a cement as strong as the natural lateral cohesion of the fibres. If this cannot be done (as it cannot in large works), the sliding is prevented by joggling the beams together, that is, by cutting down several rectangular notches in the upper side of the lower beam, and making similar notches in the under side of the upper beam, and filling up the square spaces with pieces of very hard wood firmly driven in, as represented in fig. 9. Some employ iron bolts by way of joggles. But when the joggle is much harder than the wood into which it is driven, it is very apt to work loose, by widening the hole into which it is lodged. The same thing is sometimes done by scarphing the one upon the other, as represented in fig. 10; but this wastes more timber, and is not so strong, because the mutual hooks which this method form on each beam are very apt to tear each other up. By one or other of these methods, or something similar, may a compound beam be formed, of any depth, which will be almost as stiff and strong as an entire piece.

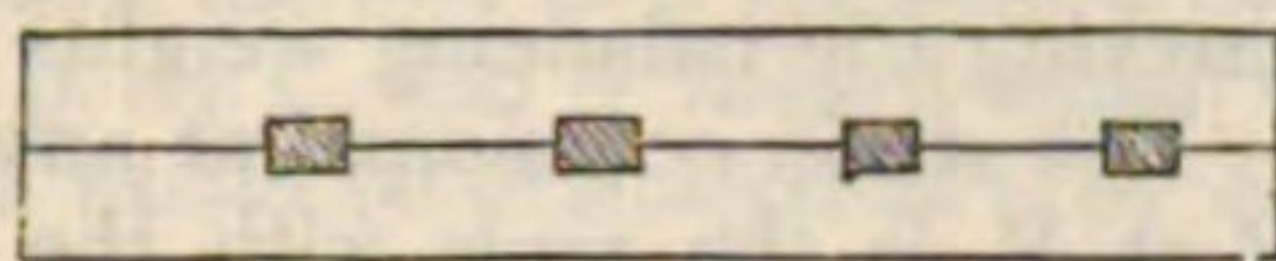


Fig. 9.

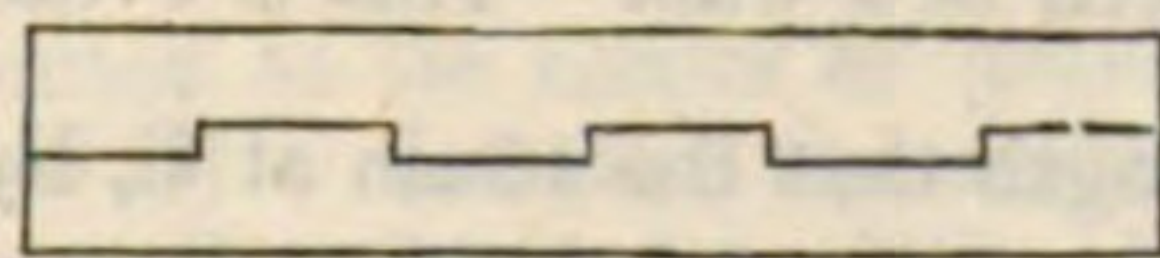


Fig. 10.

How strength may be combined with plianess. On the other hand, we may combine strength with plianess, by composing our beam of several thin planks laid on each other, till they make a proper depth, and leaving them at full liberty to slide on each other. It is in this manner that coach-springs are formed, as is represented in fig. 11. In this assemblage there must be no joggles nor bolts of any kind put through the planks or plates, for this would hinder their mutual sliding. They must be kept together by straps which surround them, or by something equivalent.

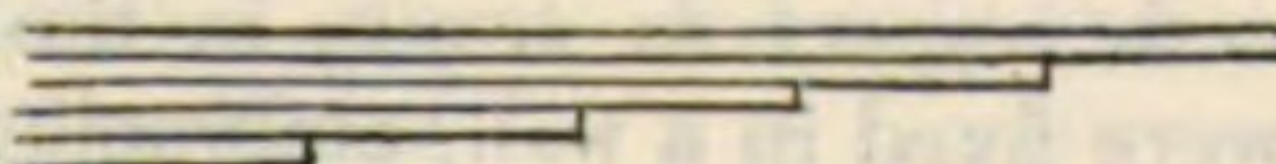


Fig. 11.

Maxims of construction. The preceding observations show the propriety of some maxims of construction, which the artists have derived from long experience.

Thus, if a mortise is to be cut out of a piece which is exposed to a cross strain, it should be cut out from that side which becomes concave by the strain.

If a piece is to be strengthened by the addition of another, the added piece must be joined to the side which grows convex by the strain.

Before we proceed any farther, it will be convenient to recall the reader's attention to the analogy between the strain on a beam projecting from a wall and loaded at the extremity, and a beam supported at both ends and loaded in some intermediate point. It is sufficient on this occasion to read attentively what is delivered in the article Roof. We learn there that the strain on the middle point C (fig. 16 of the present article) of a rectangular beam AB, supported on props at A and B, is the same as if the part CA projected from a wall, and were loaded with the half of the weight W suspended at A. The momentum of the strain

is therefore $\frac{1}{2} W \times \frac{1}{2} AB = W \times \frac{1}{4} AB = p \frac{1}{4} l$, or $\frac{pl}{4}$. The

momentum of cohesion must be equal to this in every hypothesis.

Having now considered in sufficient detail the circumstances which affect the strength of any section of a solid body that is strained transversely, it is necessary to take notice of some of the chief modifications of the strain itself. We shall consider only those that occur most frequently in our constructions.

The strain depends on the external force, and also on the lever by which it acts.

It is evidently of importance, that since the strain is exerted in any section by means of the cohesion of the parts intervening between the section under consideration and the point of application of the external force, the body must be able in all these intervening parts to propagate or excite the strain in the remote section. In every part it must be able to resist the strain excited in that part. It should therefore be equally strong; and it is useless to have any part stronger, because the piece will nevertheless break where it is not stronger throughout; and it is useless to make it stronger (relatively to its strain) in any part, for it will nevertheless equally fail in the part that is too weak.

Suppose, then, in the first place, that the strain arises from a weight suspended at one extremity, while the other end is firmly fixed in a wall. Supposing also the cross sections to be all rectangular, there are several ways of shaping the beam so that it shall be equally strong throughout. Thus it may be equally deep in every part, the upper and under surfaces being horizontal planes. The condition will be fulfilled by making all the horizontal sections triangles, as in fig. 12. The two sides are vertical planes, meeting in an edge at the extremity L. For the equation expressing the balance of strain and strength is $pl = fbd^2$. Therefore, since d^2 is the same throughout, and also p , we must have $fb = l$, and b (the breadth AD of any section ABCD) must be proportional to l (or AL), which it evidently is.

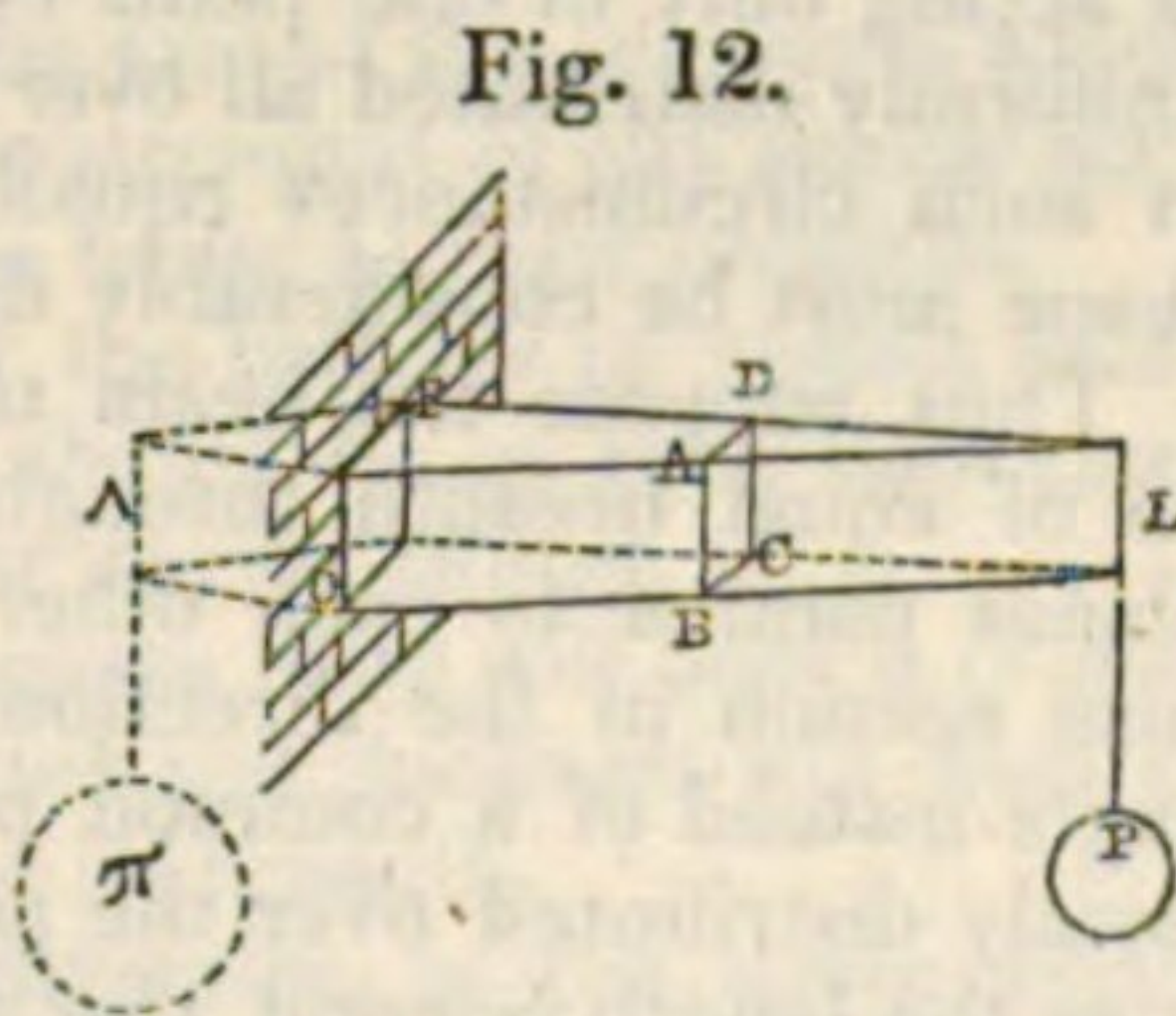


Fig. 12.

Or, if the beam be of uniform breadth, we must have d^2 everywhere proportional to l . This will be obtained by making the depths the ordinates of a common parabola, of which L is the vertex and the length is the axis. The upper or under side may be a straight line, as in fig. 13, or the middle line may be straight, and then both upper and under surfaces will be curved. It is almost indifferent what is the shape of the upper and under surfaces, provided the distances between them in every part be at the ordinates of a common parabola.

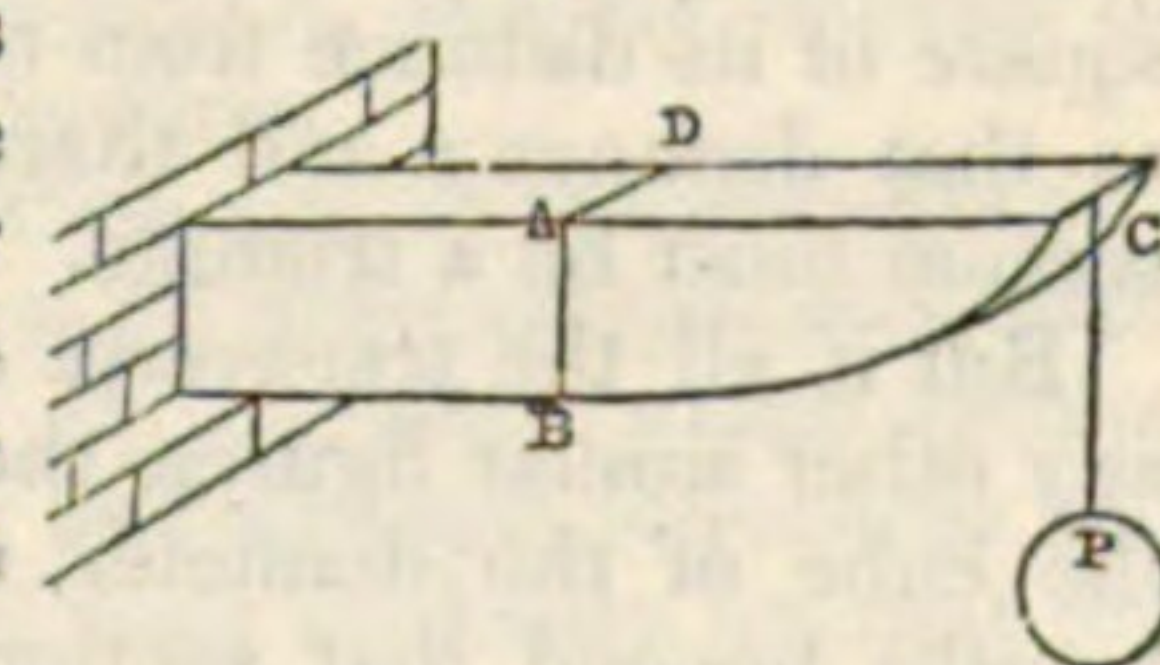


Fig. 13.

Or, if the sections are all similar, such as circles, squares, or any other similar polygons, we must have d^2 or b^3 proportional to l , and the depths or breadths must be as the ordinates of a cubical parabola.

It is evident that these are also the proper forms for a lever moveable round a fulcrum, and acted on by a force at the extremity. The force comes in the place of the weight suspended in the cases already considered; and as such levers always are connected with another arm, we readily see that both arms should be fashioned in the same manner. Thus in fig. 12 the piece of timber may be supposed a kind of steelyard, moveable round a horizontal axis in the front of the wall, and having the two weights P and π in equilibrio. The strain occasioned by each at the section in which the axis OP is placed must be the same, and each

Strength of Materials. The longitudinal sections of each arm must be a triangle, a common parabola, or a cubic parabola, according to the conditions previously given.

And, moreover, all these forms are equally strong; for any one of them is equally strong in all its parts, and they are all supposed to have the same section at the front of the wall or at the fulcrum. They are not, however, equally stiff. The first, represented in fig. 12, will bend least upon the whole, and the one formed by the cubic parabola will bend most. But their curvature at the very fulcrum will be the same in all.

It is also plain, that if the lever is of the second or third kind, that is, having the fulcrum at one extremity, it must still be of the same shape; for in abstract mechanics it is indifferent which of the three points is considered as the axis of motion. In every lever the two forces at the extremities act in one direction, and the force in the middle acts in the opposite direction, and the great strain is always at that point. Therefore a lever such as fig. 12, moveable round an axis passing horizontally through λ , and acting against an obstacle at OP, is equally able in all its parts to resist the strains excited in those parts.

The same principles and the same construction will apply to beams, such as joists, supported at the ends L and λ (fig. 12), and loaded at some intermediate part OP. This will appear evident by merely inverting the directions of the forces at these three points, or by recurring to the article Roof, p. 444.

The external straining force may be distributed over the beam. To make a beam strong which projects from a wall.

Hitherto we have supposed the external straining force as acting only in one point of the beam. But it may be uniformly distributed all over the beam. To make a beam in such circumstances equally strong in all its parts, the shape must be considerably different from the former.

Thus suppose the beam to project from a wall. If it be of equal breadth throughout, its sides being vertical planes parallel to each other and to the length, the vertical section in the direction of its length must be a triangle instead of a common parabola; for the weight uniformly distributed over the part lying beyond any section, is as the length beyond that section: and since it may all be conceived as collected at its centre of gravity, which is the middle of that length, the lever by which this load acts or strains the section is also proportioned to the same length. The strain on the section (or momentum of the load) is as the square of that length. The section must have strength in the same proportion. Its strength being as the breadth and the square of the depth, and the breadth being constant, the square of the depth of any section must be as the square of its distance from the end, and the depth must be as that distance; and therefore the longitudinal vertical section must be a triangle.

But if all the transverse sections are circles, squares, or any other similar figures, the strength of every section, or the cube of the diameter, must be as the square of the lengths beyond that section, or the square of its distance from the end; and the sides of the beam must be a semi-cubical parabola.

If the upper and under surfaces are horizontal planes, it is evident that the breadth must be as the square of the distance from the end, and the horizontal sections may be formed by arches of the common parabola, having the length for their tangent at the vertex.

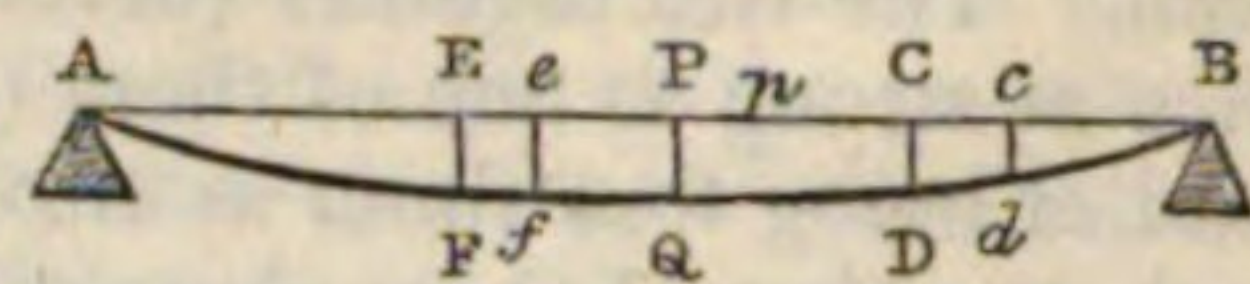
By recurring to the analogy so often quoted between a projecting beam and a joist, we may determine the proper form of joists which are uniformly loaded through their whole length.

The strain upon a beam supported at both ends.

This is a frequent and important case, being the office of joists, rafters, &c.; and there are some circumstances which must be particularly noticed, because they are not so obvious, and have been misunderstood. When a beam AB

(fig. 14) is supported at the ends, and a weight is laid on any point P, a strain is excited in every part of the beam.

Fig. 14.



The load on P causes the beam to press on A and B, and the props re-act with forces equal and opposite to these pressures. The load at P is to the pressures at A and B as AB to PB and PA, and the pressure at A is to that at B as BP to PA; the beam therefore is in the same state, with respect to strain in every part of it, as if it were resting on a prop at P, and were loaded at the ends with weights equal to the two pressures on the props: and observe, these pressures are such as will balance each other, being inversely as their distances from P. Let P represent the weight or load at P. The pressure on the prop P

must be $P \times \frac{PA}{AB}$. This is therefore the re-action of the prop

B, and is the weight which we may suppose suspended at B, when we conceive the beam resting on a prop at P, and carrying the balancing weights at A and B.

The strain occasioned at any other point C, by the load P at P, is the same with the strain at C, by the weight

$P \times \frac{PA}{AB}$ hanging at B, when the beam rests on P, in the

manner now supposed; and it is the same if the beam, instead of being balanced on a prop at P, had its part AP fixed in a wall. This is evident. Now we have shown at

length that the strain at C, by the weight $P \times \frac{PA}{AB}$ hanging

at B, is $P \times \frac{PA}{AB} \times BC$. We desire it to be particularly re-

marked, that the pressure at A has no influence on the strain at C, arising from the action of any load between A and C; for it is indifferent how the part AP of the projecting beam PB is supported. The weight at A just performs the same office with the wall in which we suppose the beam to be fixed. We are thus particular, because we have seen even persons not unaccustomed to discussions of this kind puzzled in their conceptions of this strain.

Now let the load P be laid on some point p between C and B. The same reasoning shows us that the point is, with respect to strain, in the same state as if the beam were fixed in a wall, embracing the part pB , and a weight

$= P \times \frac{pB}{AB}$ were hung on at A, and the strain at C is P

$\times \frac{pB}{AB} \times AC$.

In general, therefore, the strain on any point C, arising from a load P laid on another point P, is proportional to the rectangle of the distances of P and C from the ends nearest to each.

It is $P \times \frac{PA \times CB}{AB}$, or $P \times \frac{pB \times CA}{AB}$, according as the load lies between C and A or between C and B.

Cor. 1. The strains which a load on any point P occasions on the points C, c, lying on the same side of P, are as the distances of these points from the end B. In like manner the strains on E and e are as EA and eA.

Cor. 2. The strain which a load occasions in the part on which it rests is as the rectangle of the parts on each side. Thus the strain occasioned at C by a load is to that at D by the same load as $AC \times CB$ to $AD \times DB$. It is therefore greatest in the middle.

Let us now consider the strain on any point C arising from a load uniformly distributed along the beam. Let AP be represented by x , and Pp by dx , and the whole weight on the beam by a . Then

The strain arising from a load distributed along the beam.

Strength of
Materials.

The weight on Pp is..... $= a \frac{dx}{AB}$.

Pressure on B by the weight on $Pp = a \frac{dx}{AB} \times \frac{AP}{AB}$.

Or..... $= a \frac{xdx}{AB^2}$.

Pressure on B by whole wt. on AC $= a \frac{\frac{1}{2}AC^2}{AC^2} = a \frac{AC^2}{2AB^2}$.

Strain at C by the weight on AC $= a \frac{AC^2 \times BC}{2AB^2}$.

Strain at C by the weight on BC $= a \frac{BC^2 \times AC}{2AB^2}$.

Do. by whole weight on AB $= a \frac{AC^2 \times BC + BC^2 \times AC}{2AB^2}$

$$= a \frac{AC \times BC \times AC + CB}{2AB^2} = a \frac{AC \times BC}{2AB}$$

Thus we see that the strain is proportional to the rectangle of the parts, in the same manner as if the load a had been laid directly on the point C, and is indeed equal to one half of the strain which would be produced at C by the load a laid on there.

Mistakes on
this subject
committed
by authors
of reputa-
tion.

It was necessary to be thus particular, because we see in some elementary treatises on mechanics, published by authors of reputation, mistakes which are very plausible, and mislead the learner. It is there said that the pressure at B from a weight uniformly diffused along AB, is the same as if it were collected at its centre of gravity, which would be the middle of AB; and then the strain at C is said to be this pressure at B multiplied by BC. But surely it is not difficult to see the difference of these strains. It is plain that the pressure of gravity downwards on any point between the end A and the point C has no tendency to diminish the strain at C, arising from the upward re-action of the prop B; whereas the pressure of gravity between C and B is almost in direct opposition to it, and must diminish it. We may however avoid the fluxionary calculus with safety by the consideration of the centre of gravity, by supposing the weights of AC and BC to be collected at their respective centres of gravity; and the result of this computation will be the same as above: and we may use either method, although the weight be not uniformly distributed, provided only that we know in what manner it is distributed.

This investigation is evidently of importance in the practice of the engineer and architect, informing them what support is necessary in the different parts of their constructions. We considered some cases of this kind in the article ROOF.

To form a
joist which
may have
the same
relative
strength in
all its parts.

It is now easy to form a joist so that it shall have the same relative strength in all its parts.

I. To make it equally able in all its parts to carry a given weight laid on any point C taken at random, or uniformly diffused over the whole length, the strength of the section at the point C must be as $AC \times CB$. Therefore,

1. If the sides be parallel vertical planes, the square of the depth (which is the only variable dimension), or CD^2 , must be as $AC \times CB$, and the depths must be ordinates of an ellipse.

2. If the transverse sections be similar, we must make CD^3 as $AC \times CB$.

3. If the upper and under surfaces be parallel, the breadth must be as $AC \times CB$.

II. If the beam be necessarily loaded at some given point C, and we would have the beam equally able in all its parts to resist the strain arising from the weight at C, we must make the strength of every transverse section between C and either end as its distance from that end. Therefore,

VOL. XX.

1. If the sides be parallel vertical planes, we must make $CD^2 : EF^2 = AC : AE$.

2. If the sections be similar, then $CD^3 : EF^3 = AC : AE$.

3. If the upper and under surfaces be parallel, then breadth at C : breadth at E $= AC : AE$.

The same principles enable us to determine the strain and strength of square or circular plates of different extent but equal thickness. This may be comprehended in this general proposition.

Similar plates of equal thickness supported all round will carry the same absolute weight, uniformly distributed, or resting on similar points, whatever be their extent.

Suppose two similar oblong plates of equal thickness, and let their lengths and breadths be L, l , and B, b . Let their strength or momentum of cohesion be C, c , and the strains from the weights W, w , be S, s .

Suppose the plates supported at the ends only, and resisting fracture transversely. The strains, being as the weights and lengths, are as WL and wl , but their cohesions are as the breadths; and since they are of equal relative strength, we have $WL : wl = B : b$, and $WLb = wlb$, and $L : l = wB : Wb$; but since they are of similar shapes, $L : l = B : b$, and therefore $w = W$.

The same reasoning holds again when they are also supported along the sides, and therefore holds when they are supported all round (in which case the strength is doubled).

And if the plates be of any other figure, such as circles or ellipses, we need only conceive similar rectangles inscribed in them. These are supported all around by the continuity of the plates, and therefore will sustain equal weights; and the same may be said of the segments which lie without them, because the strengths of any similar segments are equal, their lengths being as their breadths.

Therefore the thickness of the bottoms of vessels holding heavy liquors or grains should be as their diameters and as the square root of their depths jointly.

Also the weight which a square plate will bear is to that which a bar of the same matter and thickness will bear as twice the length of the bar to its breadth.

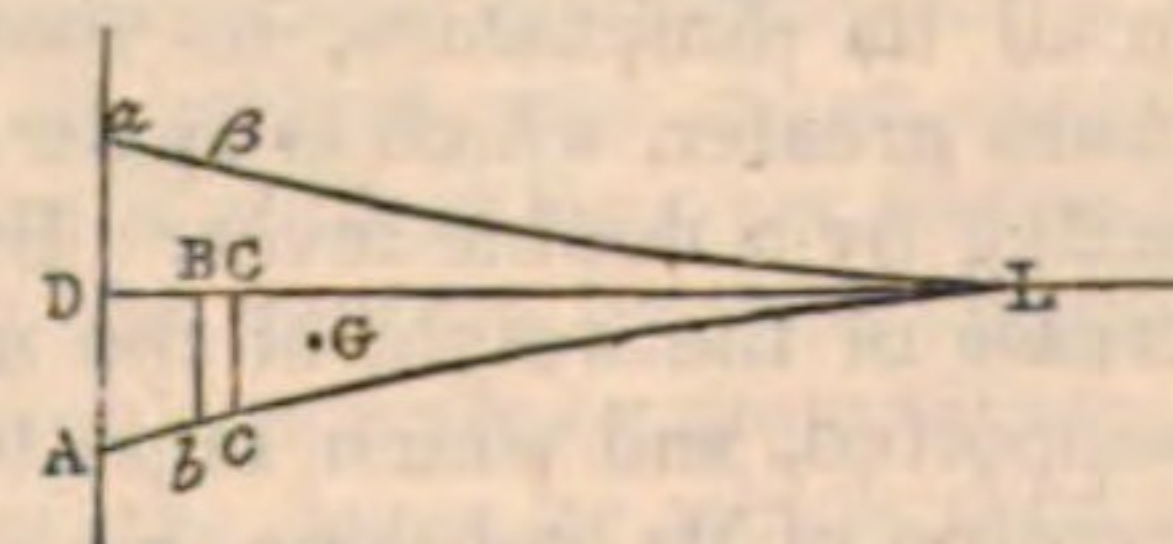
There is yet another modification of the strain which tends to break a body transversely, which is of very frequent occurrence, and in some cases must be very carefully attended to, viz. the strain arising from its own weight.

When a beam projects from a wall, every section is strained by the weight of all that projects beyond it. This may be considered as all collected at its centre of gravity. Therefore the strain on any section is in the joint ratio of the weight of what projects beyond it, and the distance of its centre of gravity from the section.

The determination of this strain, and of the strength necessary for withstanding it, must be more complicated than the former, because the form of the piece which results from this adjustment of strain and strength influences the strain. The general principle must evidently be, that the strength or momentum of cohesion of every section must be as the product of the weight beyond it, multiplied by the distance of its centre of gravity. For example:

Suppose the beam DLA (fig. 15) to project from the wall, and that its sides are parallel vertical planes, so that the depth is the only variable dimension. Let $LB = x$ and $Bb = y$. The element Bbc is $= xy$. Let G be the centre of gravity of the part lying without Bb , and g be its distance from the extremity L . Then $x - g$ is the arm of the lever by which the strain is excited in the section Bb .

Fig. 15.



Strength of
Materials.

The strain
and
strength of
square or
circular
plates of
different
extent but
of equal
thickness
may be de-
termined
from the
same prin-
ciples.

The strain
of a beam
arising from
its own
weight.

General
principle
respecting
it.

Strength of Materials. Let Bb or y be as some power m of LB ; that is, let

$y = x^m$. Then the contents of LBb is $\frac{x^{m+1}}{m+1}$. The

momentum of gravity round a horizontal axis at L is $yxdx = x^{m+2}dx$, and the whole momentum round the axis is

$\frac{x}{m+2}$. The distance of the centre of gravity from L is

had by dividing this momentum by the whole weight, which

is $\frac{x^{m+1}}{m+1}$. The quotient or g is $\frac{x \times m+1}{m+2}$, and the dis-

tance of the centre of gravity from the section Bb is

$x - \frac{x \times m+1}{m+2} = \frac{x \times m+2 - x \times m+1}{m+2} = \frac{x}{m+2}$. There-

fore the strain on the section Bb is had by multiplying

$\frac{x^{m+1}}{m+1}$ by $\frac{x}{m+2}$. The product is $\frac{x^{m+2}}{m+2 \times m+1}$. This

must be as the square of the depth, or as y^2 . But y is as x^m , and y^2 as x^{2m} . Therefore we have $m+2 = 2m$, and $m = 2$; that is, the depth must be as the square of the distance from the extremity, and the curve LbA is a parabola touching the horizontal line in L .

A conoid equally able in every section to bear its own weight. It is easy to see that a conoid formed by the rotation of this figure round DL will also be equally able in every section to bear its own weight.

We need not prosecute this farther. When the figure of the piece is given, there is no difficulty in finding the strain; and the circumstance of equal strength to resist this strain is chiefly a matter of curiosity.

The more a beam projects, the less able it is to bear its own weight. It is evident, from what has been already said, that a projecting beam becomes less able to bear its own weight as it projects farther. Whatever may be the strength of the section DA , the length may be such that it will break by its own weight. If we suppose two beams A and B of the same substance and similar shapes, that is, having their lengths and diameters in the same proportion; and further suppose that the shorter can just bear its own weight; then the longer beam will not be able to do the same; for the strengths of the sections are as the cubes of the diameters, while the strains are as the biquadrates of the diameters; because the weights are as the cubes, and the levers by which these weights act in producing the strain are as the lengths or as the diameters.

Small bodies more able to withstand the strain produced by the weight of the machine than great bodies. These considerations show us, that in all cases where strain is affected by the weight of the parts of the machine or structure of any kind, the smaller bodies are more able to withstand it than the greater; and there seem to be bounds set by nature to the size of machines constructed of any given materials. Even when the weight of the parts of the machine is not taken into the account, we cannot enlarge them in the same proportion in all their parts. Thus a steam-engine cannot be doubled in all its parts, so as to be still efficient. The pressure on the piston is quadrupled. If the lift of the pump be also doubled in height while it is doubled in diameter, the load will be increased eight times, and will therefore exceed the power. The depth of lift, therefore, must remain unchanged; and in this case the machine will be of the same relative strength as before, independent of its own weight. For the beam being doubled in all its dimensions, its momentum of cohesion is eight times greater, which is again a balance for a quadruple load acting by a double lever. But if we now consider the increase of the weight of the machine itself, which must be supported, and which must be put in motion by the intervention of its cohesion, we see that the large machine is weaker and less efficient than the small one.

There is a similar limit set by nature to the size of plants and animals formed of the same matter. The cohesion of

an herb could not support it if it were increased to the size of a tree, nor could an oak support itself if forty or fifty times bigger; nor could an animal of the make of a long-legged spider be increased to the size of a man; the articulations of its legs could not support it.

Hence may be understood the prodigious superiority of the small animals both in strength and agility. A man by falling twice his own height may break his firmest bones. A mouse may fall twenty times its height without risk; and even the tender mite or wood-louse may fall unhurt from the top of a steeple. But their greatest superiority is in respect of nimbleness and agility. A flea can leap above 500 times its own length, while the strength of the human muscles could not raise the trunk from the ground on limbs of the same construction.

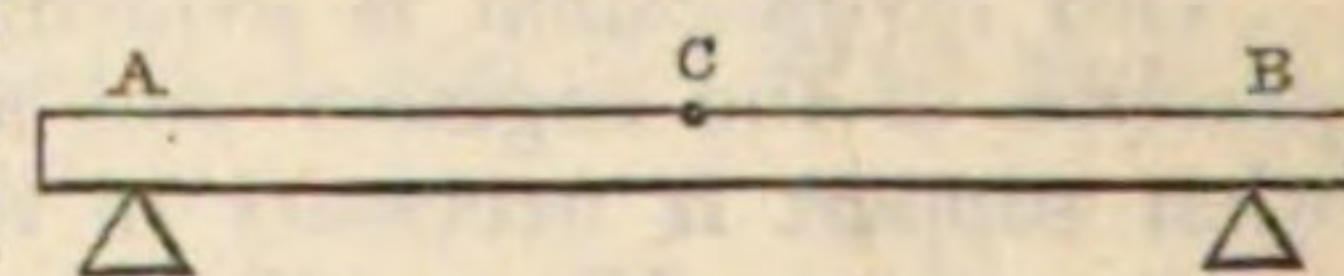
The angular motions of small animals (in which consists their nimbleness or agility) must be greater than those of large animals, supposing the force of the muscular fibre to be the same in both. For supposing them similar, the number of equal fibres will be as the square of their linear dimensions; and the levers by which they act are as their linear dimensions. The energy therefore of the moving force is as the cube of these dimensions. But the momen-

tum of inertia, or $\int p \cdot r^2$, is as the fourth power; therefore

the angular velocity of the greater animals is smaller. The number of strokes which a fly makes with its wings in a second is astonishingly great; yet, being voluntary, they are the effects of its agility.

We have hitherto confined our attention to the simplest form in which this transverse strain can be produced. This was quite sufficient for showing us the mechanism of nature by which the strain is resisted; and a very slight attention is sufficient for enabling us to reduce to this every other way in which the strain can be produced. We shall not take up the reader's time with the application of the same principles to other cases of this strain, but refer him to what has been said in the article *Roof*. In that article we have shown the analogy between the strain on the section of a beam projecting from a wall and loaded at the extremity, and the strain on the same section of a beam simply resting on supports at the ends, and loaded at some intermediate point or points. The strain on the middle C of a beam AB (fig. 16) so supported, arising from a weight laid on there, is the same with the strain which half that weight hanging at B would produce on the same section C , if the other end of the beam were fixed in a wall.

Fig. 16.



If therefore 1000 pounds hung on the end of a beam projecting ten feet from a wall will just break it at the wall, it will require 4000 pounds on its middle to break the same beam resting on two props ten feet asunder. We have also shown in that article the additional strength which will be given to this beam by extending both ends beyond the props, and there framing it firmly into other pillars or supports. We can hardly add any thing to what has been said in that article, except a few observations on the effects of the obliquity of the external force. We have hitherto supposed it to act in the direction BP (fig. 6) perpendicular to the length of the beam. Suppose it to act in the direction BP' , oblique to BA . In the article *Roof* we supposed the strain to be the same as if the force p acted at the distance AB' , but still perpendicular to AB : so it is. But the strength of the section $A\Delta$ is not the same in both cases; for by the obliquity of the action the piece $DCK\Delta$ is pressed to the other. We are not sufficiently acquainted with the corpuscular forces to say precisely what will be the effect of the pressure arising from this obliquity; but we can clearly see in general, that the point A , which in the instant of fracture

Effects of obliquity of the external force.

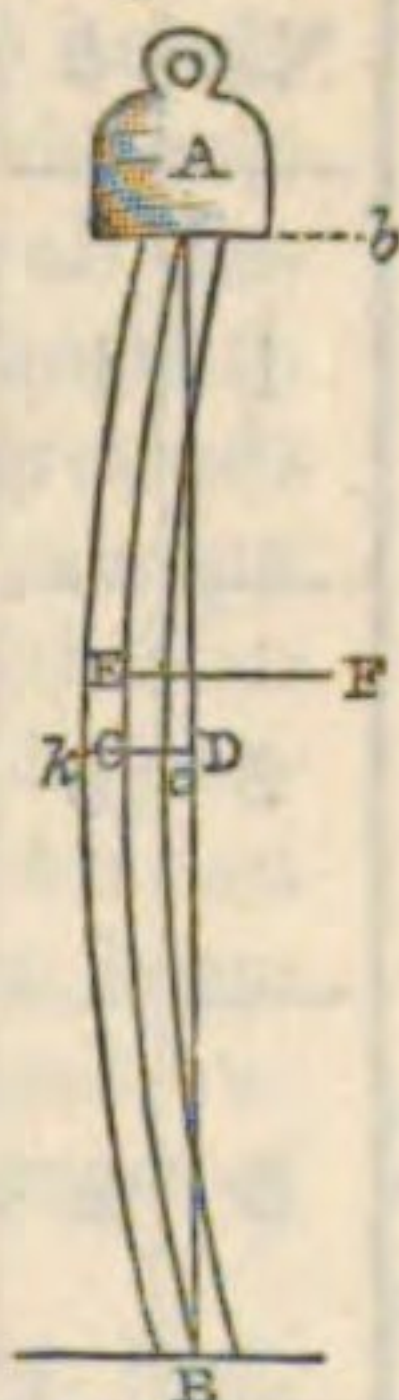
Strength of Materials. is neither stretched nor compressed, must now be farther up, or nearer to D; and therefore the number of particles which are exerting cohesive forces is smaller, and therefore the strength is diminished. Therefore, when we endeavour to proportion the strength of a beam to the strain arising from an external force acting obliquely, we make too liberal allowance by increasing this external force in the ratio of AB to AB'. We acknowledge our inability to assign the proper correction. But this circumstance is of very great influence. In many machines, and many framings of carpentry, this oblique action of the straining force is unavoidable; and the most enormous strains to which materials are exposed are generally of this kind. In the frames set up for carrying the ringstones of arches, it is hardly possible to avoid them; for although the judicious engineer dispose his beams so as to sustain only pressures in the direction of their lengths, tending either to crush them or to tear them asunder, it frequently happens that, by the settling of the work, the pieces come to check and bear on each other transversely, tending to break each other across. This we have remarked upon in the article Roof, with respect to a truss by Mr Price (see Roof, p. 452-54). Now when a cross strain is thus combined with an enormous pressure in the direction of the length of the beam, it is in the utmost danger of snapping suddenly across. This is one great cause of the carrying away of masts. They are compressed in the direction of their length by the united force of the shrouds, and in this state the transverse action of the wind soon completes the fracture.

The strain on columns. When considering the compressing strains to which materials are exposed, we deferred the discussion of the strain on columns, observing that it was not, in the cases which usually occur, a simple compression, but was combined with a transverse strain, arising from the bending of the column. When the column ACB (fig. 17), resting on the ground at B, and loaded at top with a weight A, acting in the vertical direction AB, is bent into a curve ACB, so that the tangent at C is perpendicular to the horizon, its condition somewhat resembles that of a beam firmly fixed between B and C, and strongly pulled by the end A, so as to bend it between C and A. Although we cannot conceive how a force acting on a straight column AB in the direction AB can bend it, we may suppose that the force acted first in the horizontal direction Ab till it was bent to this degree, and that the rope was then gradually removed from the direction Ab to the direction AB, increasing the force as much as is necessary for preserving the same quantity of flexure.

Observations on Euler's theory of the strength of columns. The first author, we believe, who considered this important subject with scrupulous attention was the celebrated Euler, who published in the Berlin Memoirs for 1757 his Theory of the Strength of Columns. The general proposition established by this theory is, that the strength of prismatical columns is in the direct quadruplicate ratio of their diameters, and the inverse duplicate ratio of their lengths. He prosecuted this subject in the Petersburg Commentaries for 1778, confirming his former theory. We do not find that any other author has bestowed much attention on it, all seeming to acquiesce in the determinations of Euler, and to consider the subject as of very great difficulty, requiring the application of the most refined mathematics. Muschenbroeck has compared the theory with experiment; but the comparison has been very unsatisfactory, the difference from the theory being so enormous as to afford no argument for its justness. But the experiments do not contradict it, for they are so anomalous as to afford no conclusion or general rule whatever.

To say the truth, the theory can be considered in no

Fig. 17.



other light than as a specimen of ingenious and very artful algebraic analysis. Euler was unquestionably the first Strength of Materials. analyst in Europe for resource and address. He knew this, and enjoyed his superiority, and without scruple admitted any physical assumptions which gave him an opportunity of displaying his skill. The inconsistency of his assumptions with the known laws of mechanism gave him no concern; and when his algebraic processes led him to any conclusion which would make his readers stare, being contrary to all our usual notions, he frankly owned the paradox, but went on in his analysis, saying, *Sed analysi magis fidendum*. Mr Robins has given some very risible instances of this confidence in his analysis, or rather of his confidence in the indolent submission of his readers. Nay, so fond was he of this kind of amusement, that after having published an untenable Theory of Light and Colours, he published several Memoirs, explaining the aberration of the heavenly bodies, deducing some very wonderful consequences, fully confirmed by experience, from the Newtonian principles, which were opposite and totally inconsistent with his own theory, merely because the Newtonian theory gave him *occasionem analyseos promovendæ*. We are thus severe in our observations, because his Theory of the Strength of Columns is one of the strongest instances of this wanton kind of proceeding, and because his followers in the Academy of St Petersburg, such as Fuss, Lexell, and others, adopt his conclusions, and merely echo his words. Since the death of Daniel Bernoulli, no member of that academy has controverted any thing advanced by their *Professor sublimis Geometriæ*, to whom they had been indebted for their places and for all their knowledge, having been (most of them) his amanuenses, employed by this wonderful man during his blindness, to make his computations and carry on his algebraic investigations. We are not a little surprised to see Mr Emerson, a considerable mathematician, and a man of very independent spirit, hastily adopting the same theory, of which we doubt not but our readers will easily see the falsity.

Euler considers the column ACB as in a condition precisely similar to that of an elastic rod bent into the curve by a cord AB connecting its extremities. In this he is not mistaken. But he then draws CD perpendicular to AB, and considers the strain on the section C as equal to the momentum or mechanical energy of the weight A, acting in the direction DE, upon the lever *kcD*, moveable round the fulcrum *c*, and tending to tear asunder the particles which cohere along the section *cCk*. This is the same principle (as Euler admits) employed by James Bernoulli in his investigation of the elastic curve ACB. Euler considers the strain on the section *ck* as the same with what it would sustain if the same power acted in the horizontal direction EF on a point E, as far removed from C as the point D is. We reasoned in the same manner (as has been observed) in the article Roof, where the obliquity of action was inconsiderable. But in the present case this substitution leads to the greatest mistakes, and has rendered the whole of this theory false and useless. It would be just if the column were of materials which are incompressible. But it is evident, by what has been said above, that by the compression of the parts the real fulcrum of the lever shifts away from the point *c*, so much the more as the compression is greater. In the great compressions of loaded columns, and the almost unmeasurable compressions of the truss-beams in the centres of bridges, and other cases of chief importance, the fulcrum is shifted far over towards *k*, so that very few fibres resist the fracture by their cohesion, and these few have a very feeble energy or momentum, on account of the short arm of the lever by which they act. This is a most important consideration in carpentry, yet makes no element of Euler's theory. The consequence of this is, that a very small degree of curvature is sufficient

Strength of Materials. to cause the column or strut to snap in an instant, as is well known to every experienced carpenter. The experiment by Muschenbroeck, which Euler makes use of in order to obtain a measure of strength in a particular instance, from which he might deduce all others by his theorem, is an incontestable proof of this. The force which broke the column is not the twentieth part of what is necessary for breaking it by acting at E in the direction EF. Euler takes no notice of this immense discrepancy, because it must have caused him to abandon the speculation with which he was then amusing himself.

This theory false and useless.

The limits of this work do not afford room to enter minutely upon the refutation of this theory; but we can easily show its uselessness, by its total inconsistency with common observation. It results legitimately from this theory, that if CD have no magnitude, the weight A can have no momentum, and the column cannot be broken. True, it cannot be broken in this way, snapped by a transverse fracture, if it do not bend; but we know very well that it can be crushed or crippled, and we see this frequently happen. This circumstance or event does not enter into Euler's investigation, and therefore the theory is at least imperfect and useless. Had this crippling been introduced in the form of a physical assumption, every topic of reasoning employed in the process must have been laid aside, as the intelligent reader will easily see. But the theory is not only imperfect, but false. The ordinary reader will be convinced of this by another legitimate consequence of it. Fig. 18 is the same with fig. 106 of Emerson's Mechanics, where this subject is treated on Euler's principles, and represents a crooked piece of matter resting on the ground at F, and loaded at A with a weight acting in the vertical direction AF. It results from Euler's theory that the strains at b, B, D, E, &c. are as bc , BC , DI , EK , &c. Therefore the strains at G and H are nothing; and this is asserted by Emerson and Euler as a serious truth; and the piece may be thinned *ad infinitum* in these two places, or even cut through, without any diminution of its strength. The absurdity of this assertion strikes at first hearing. Euler asserts the same thing with respect to a point of contrary flexure. Farther discussion is, we apprehend, needless.

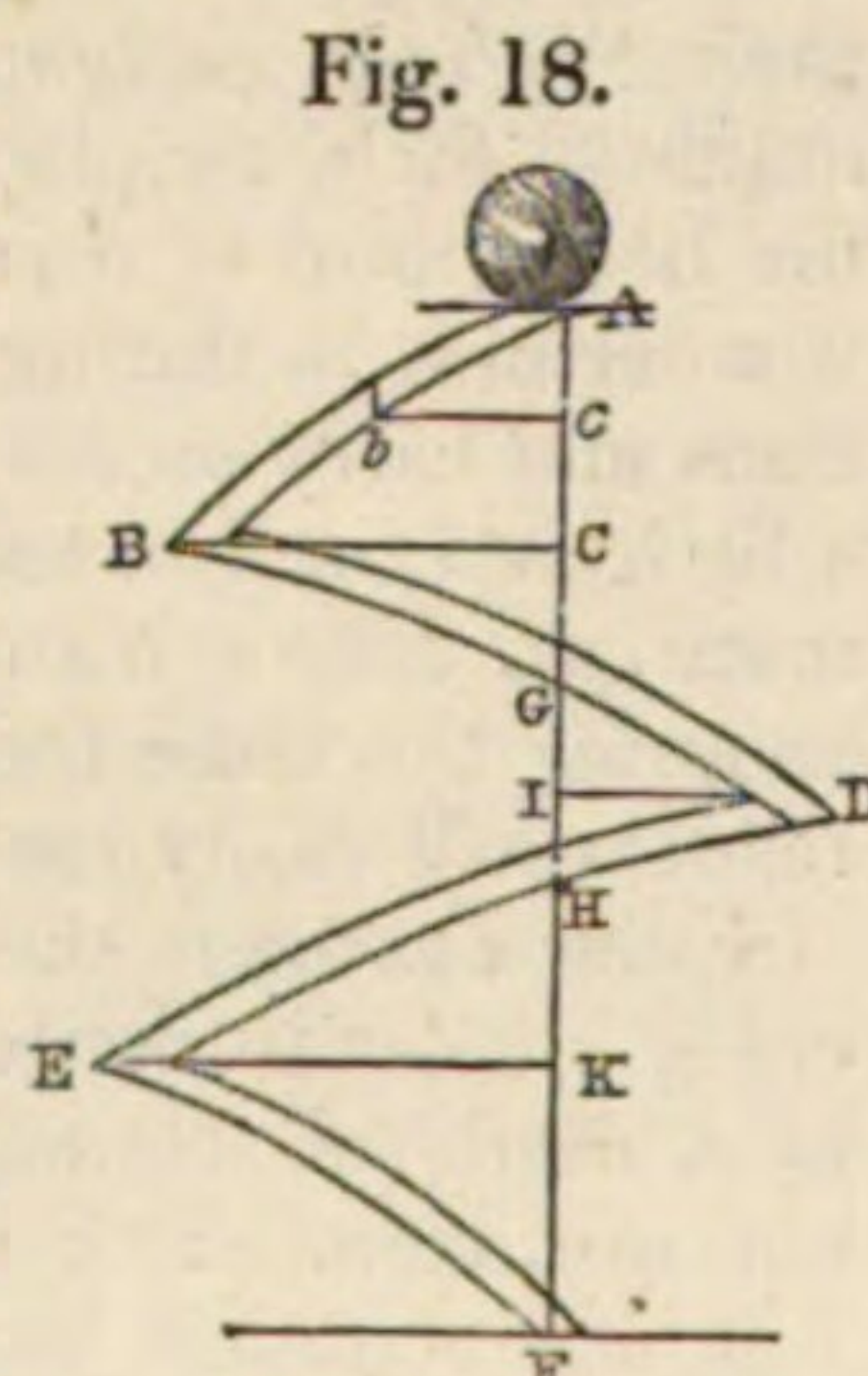


Fig. 18.

Yet Euler's dissertations deserve a perusal.

This theory must therefore be given up. Yet these dissertations of Euler in the Petersburg Commentaries deserve a perusal, both as very ingenious specimens of analysis, and because they contain maxims of practice which are important. Although they give an erroneous measure of the comparative strength of columns, they show the immense importance of preventing all bendings, and point out with accuracy where the tendencies to bend are greatest, and how this may be prevented by very small forces, and what a prodigious accession of force this gives the column. There is a valuable paper in the same volume by Fuss on the Strains on framed Carpentry, which may also be read with advantage.

A new theory cannot be substituted in place of Euler's till many experiments be made.

It will now be asked, what shall be substituted in place of this erroneous theory? what is the true proportion of the strength of columns? We acknowledge our inability to give a satisfactory answer. This can only be obtained by a previous knowledge of the proportion between the extensions and compressions produced by equal forces, by the knowledge of the absolute compressions producible by a given force, and by a knowledge of the degree of that derangement of parts which is termed crippling. These circumstances are but imperfectly known to us, and there lies before us a wide field of experimental inquiry. Fortunately

the force requisite for crippling a beam is prodigious, and a very small lateral support is sufficient to prevent that bending which puts the beam in imminent danger. A judicious engineer will always employ transverse bridles, as they are called, to stay the middle of long beams which are employed as pillars, struts, or truss-beams, and are exposed, by their position, to enormous pressures in the direction of their lengths. Such stays may be observed, disposed with great judgment and economy, in the centres employed by Mr Perronet in the erection of his great stone arches. He was obliged to correct this omission made by his ingenious predecessor in the beautiful centres of the bridge of Orleans, which we have no hesitation in affirming to be the finest piece of carpentry in the world.

It only remains on this head to compare these theoretical deductions with experiment.

Experiments on the transverse strength of bodies are easily made, and accordingly are very numerous, especially those made on timber, which is the case most common and most interesting. But in this great number of experiments there are very few from which we can draw much practical information. The experiments have in general been made on such small scantlings, that the unavoidable natural inequalities bear too great a proportion to the strength of the whole piece. Accordingly, when we compare the experiments of different authors, we find them differ enormously, and even the experiments by the same author are very anomalous. The completest series that we have yet seen is that detailed by Belidor in his *Science des Ingenieurs*. They are contained in the following table. The pieces were sound, even-grained oak. The column b contains the breadths of the pieces in inches; the column d contains their depths; the column l contains their lengths; column p contains the weights (in pounds) which broke them when hung on their middles; and m is the column of averages or mediums.

Table of experiments made by Belidor.

No.	b	d	l	p	m	
1	1	1	18	400 415 405	406	The ends lying loose.
2	1	1	18	600 600 624	608	The ends firmly fixed.
3	2	1	18	810 795 812	805	Loose.
4	1	2	18	1570 1580 1590	1580	Loose.
5	1	1	36	185 195 180	187	Loose.
6	1	1	36	285 280 285	283	Fixed.
7	2	2	36	1550 1620 1585	1585	Loose.
8	$2\frac{1}{3}$	$2\frac{1}{3}$	36	1665 1675 1640	1660	Loose.

Strength of Materials. By comparing Experiments 1st and 3d, the strength appears proportional to the breadth.

Corollaries derived from them. Experiments 3d and 4th show the strength proportional to the square of the depth.

Experiments 1st and 5th show the strength nearly in the inverse proportion of the lengths, but with a sensible deficiency in the longer pieces.

Experiments 5th and 7th show the strengths proportional to the breadths and the square of the depth.

Experiments 1st and 7th show the same thing, compounded with the inverse proportion of the length: here the deficiency relative to the length is not so remarkable.

Experiments 1st and 2d, and experiments 5th and 6th, show the increase of strength, by fastening the ends, to be in the proportion of two to three. The theory gives the proportion of two to four. But a difference in the manner of fixing may produce this deviation from the theory, which only supposed them to be held down at places beyond the props, as when a joist is held in the walls, and also rests on two pillars between the walls.

The chief source of irregularity in such experiments is the fibrous, or rather plated texture of timber. It consists of annual additions, whose cohesion with each other is vastly weaker than that of their own fibres. Let fig. 19 represent the section of a tree, and

ABCD, abcd the section of two battens that are to be cut out of it for experiment, and let AD and ad be the depths, and DC, dc the breadths. The batten ABCD will be the stronger, for the same reason that an assemblage of planks set edgewise will form a stronger joist than planks laid above each other like the plates of a coach-spring. M. Buffon found by many trials that the strength of ABCD was to that of abcd (in oak) nearly as eight to seven. The authors of the different experiments were not careful that their battens had their plates all disposed similarly with respect to the strain. But even with this precaution they would not have afforded sure grounds of computation for large works; for great beams occupy much, if not the whole, of the section of the tree; and from this it has happened that their strength is less than in proportion to that of a small lath or batten. In short, we can trust no experiments but such as have been made on large beams. These must be very rare, for they are most expensive and laborious, and exceed the abilities of most of those who are disposed to study this subject.

But we are not wholly without such authority. M. Buffon and M. Duhamel, two of the first philosophers and mechanicians of the age, were directed by government to make experiments on this subject, and were supplied with ample funds and apparatus. The relation of their experiments is to be found in the Memoirs of the French Academy for 1740, 1741, 1742, 1768; as also in Duhamel's valuable performances *Sur l'Exploitation des Arbres, et sur la Conservation et le Transport de Bois*. We earnestly recommend these dissertations to the perusal of our readers, as containing much useful information relative to the strength of timber, and the best methods of employing it. We shall here give an abstract of M. Buffon's experiments.

M. Buffon's experiments on bars of sound oak. He relates a great number which, during two years, he had prosecuted on small battens. He found that the odds of a single layer, or part of a layer, more or less, or even a different disposition of them, had such influence that he was obliged to abandon this method, and to have recourse to the largest beams that he was able to break. The following table exhibits one series of experiments on bars of sound

oak, clear of knots, and four inches square. This is a specimen of all the rest.

Column 1st is the length of the bar in clear feet between the supports.

Column 2d is the weight of the bar (the second day after it was felled) in pounds. Two bars were tried of each length. Each of the first three pairs consisted of two cuts of the same tree. The one next the root was always found the heaviest, stiffest, and strongest. Indeed M. Buffon says that this was invariably true, that the heaviest was always the strongest; and he recommends it as a certain (or sure) rule for the choice of timber. He finds that this is always the case when the timber has grown vigorously, forming very thick annual layers. But he also observes that this is only during the advances of the tree to maturity; for the strength of the different circles approaches gradually to equality during the tree's healthy growth, and then it decays in these parts in a contrary order. Our tool-makers assert the same thing with respect to beech: yet a contrary opinion is very prevalent; and wood with a fine, that is, a small grain, is frequently preferred. Perhaps no person has ever made the trial with such minuteness as M. Buffon, and we think that much deference is due to his opinion.

Column 3d is the number of pounds necessary for breaking the tree in the course of a few minutes.

Column 4th is the number of inches which it bent down before breaking.

Column 5th is the time at which it broke.

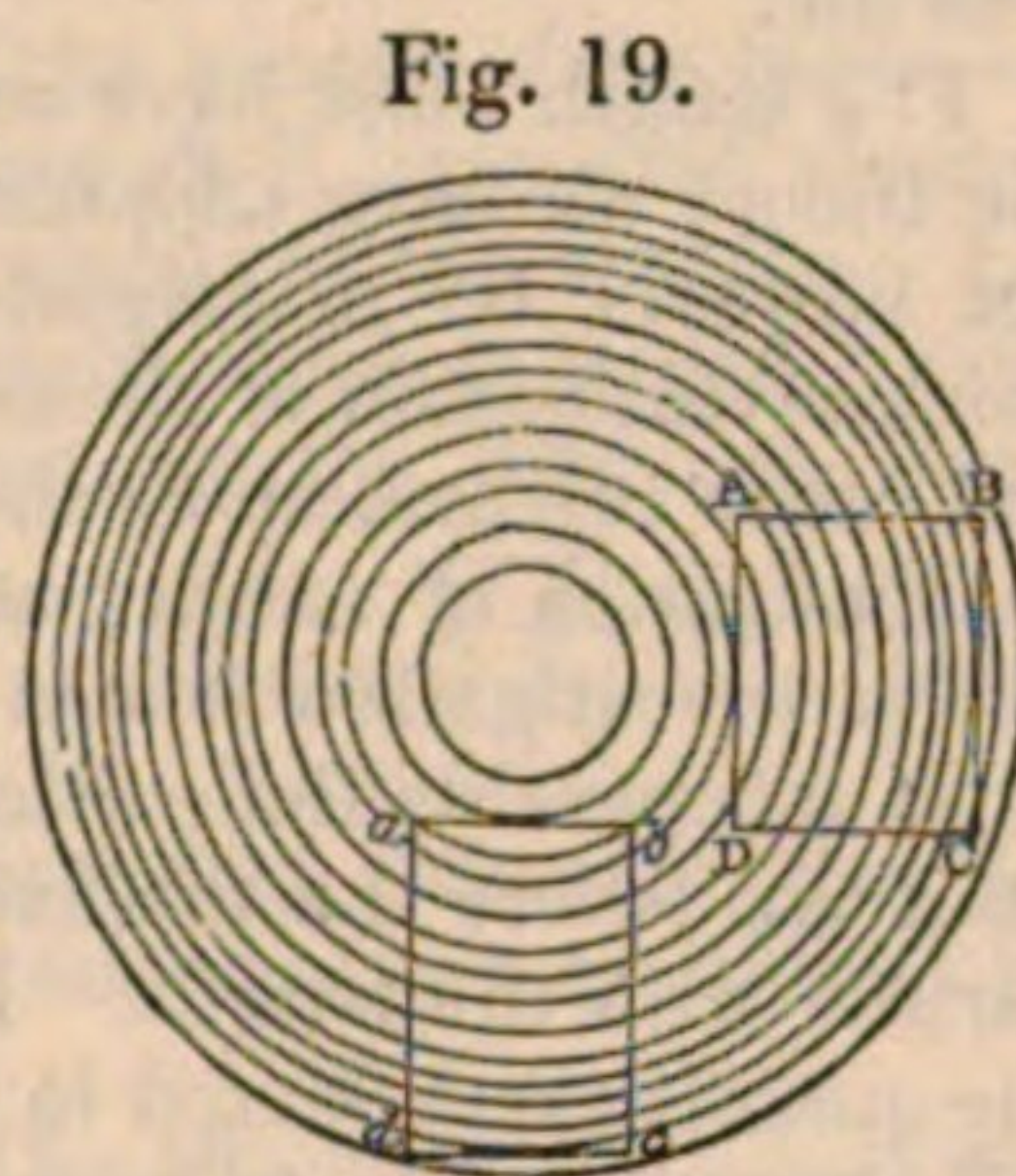


Fig. 19.

1	2	3	4	5
7	{ 60 56	5350 5275	3.5 4.5	29 22
8	{ 68 63	4600 4500	3.75 4.7	15 13
9	{ 77 71	4100 3950	4.85 5.5	14 12
10	{ 84 82	3625 3600	5.83 6.5	15 15
12	{ 100 98	3050 2925	7. 8.	

The experiments on other sizes were made in the same way. A pair at least of each length and size was taken. The mean results are contained in the following table. The beams were all square, and their sizes in inches are placed at the head of the columns, and their lengths in feet are in the first column.

	4	5	6	7	8	A
7	5312	11525	18950	32200	47649	11525
8	4550	9787	15525	26050	39750	10085
9	4025	8308	13150	22350	32800	8964
10	3612	7125	11250	19475	27750	8068
12	2987	6075	9100	16175	23450	6723
14	...	5300	7475	13225	19775	5763
16	...	4350	6362	11000	16375	5042
18	...	3700	5562	9245	13200	4482
20	...	3225	4950	8375	11487	4034
22	...	2975	...	...	...	3667
24	...	2162	...	...	...	3362
28	...	1775	...	...	...	2881

M. Buffon had found, by numerous trials, that oak-timber lost much of its strength in the course of drying or season-

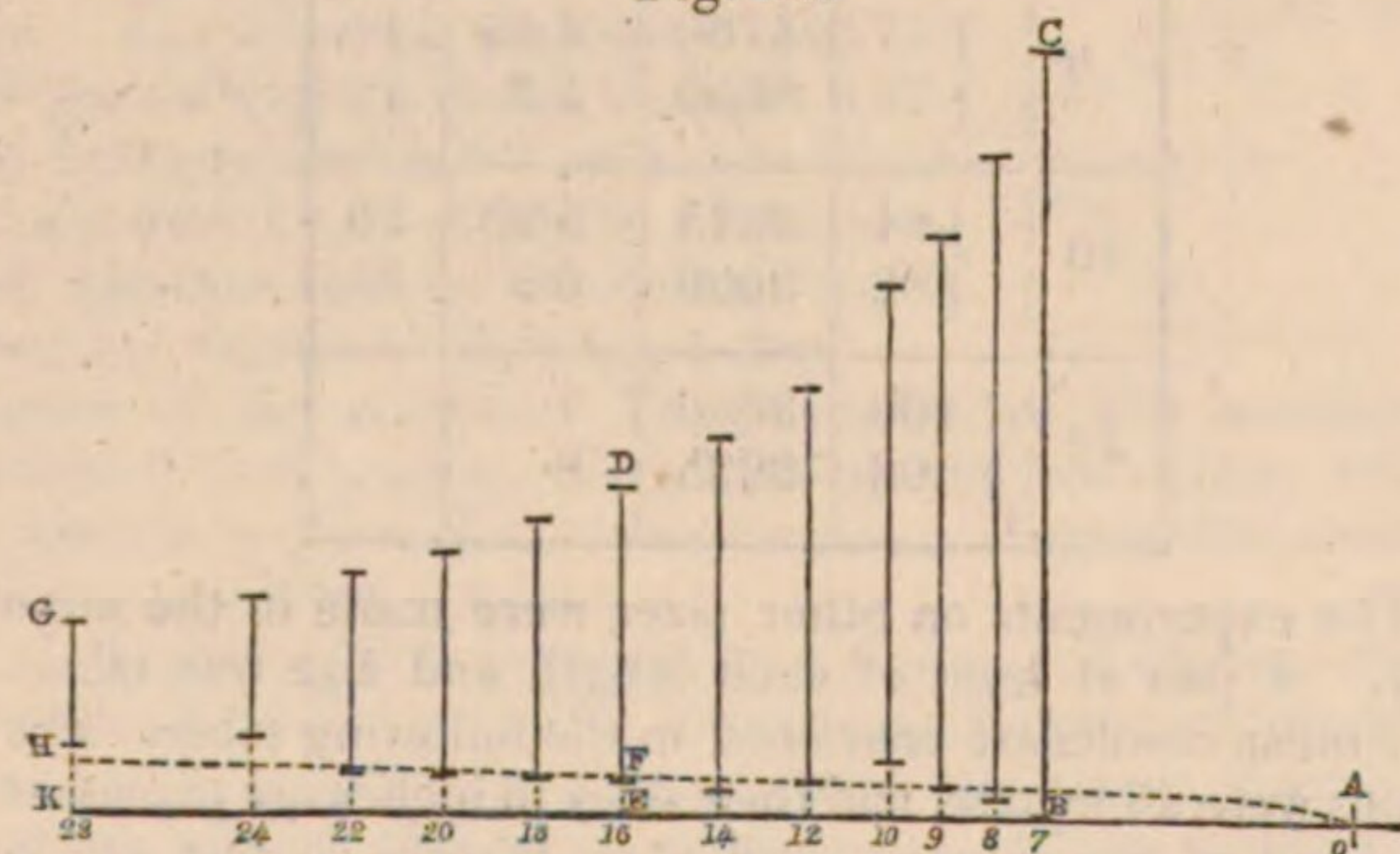
Strength of Materials. ing; and therefore, in order to secure uniformity, his trees were all felled in the same season of the year, were squared the day after, and tried the third day. Trying them in this green state gave him an opportunity of observing a very curious and unaccountable phenomenon. When the weights were laid briskly on, nearly sufficient to break the log, a very sensible smoke was observed to issue from the two ends with a sharp hissing noise. This continued all the while the tree was bending and cracking. This shows that the log is affected or strained through its whole length. Indeed this must be inferred from its bending through its whole length. It also shows us the great effects of the compression. It is a pity M. Buffon did not take notice whether this smoke issued from the upper or compressed half of the section only, or whether it came from the whole.

Observations on M. Buffon's experiments. We must now make some observations on these experiments, in order to compare them with the theory which we have endeavoured to establish.

M. Buffon considers the experiments with the five-inch bars as the standard of comparison, having both extended these to greater lengths, and having tried more pieces of each length.

Our theory determines the relative strength of bars of the same section to be inversely as their lengths. But, if we except the five experiments in the first column, we find a very great deviation from this rule. Thus the five-inch bar of twenty-eight feet long should have half the strength of that of fourteen feet, or 2650; whereas it is but 1775. The bar of fourteen feet should have half the strength of that of seven feet, or 5762; whereas it is but 5300. In like manner, the fourth of 11,525 is 2881; but the real strength of the twenty-eight feet bar is 1775. We have added a column A, which exhibits the strength which each of the five-inch bars ought to have by the theory. This deviation is most distinctly seen in fig. 20, where BK is the scale

Fig. 20.



of lengths, B being at the point seven of the scale, and K at twenty-eight. The ordinate CB is = 11,525, and the other ordinates DE, GK, &c. are respectively = $\frac{7CB}{\text{length}}$. The lines DF, GH, &c. are made = 4350, 1775, &c., expressing the strengths given by experiment. The ten-foot bar and the twenty-four feet bar are remarkably anomalous. But all are deficient, and the defect has an evident progression from the first to the last. The same thing may be shown of the other columns, and even of the first, though it is very small in that column. It may also be observed in the experiments of Belidor, and in all that we have seen. We cannot doubt therefore of its being a law of nature, depending on the true principles of cohesion and the laws of mechanics.

But it is very puzzling, and we cannot pretend to give a satisfactory explanation of the difficulty. The only effect which we can conceive the length of a beam to have, is to increase the strain at the section of fracture, by employing the intervening beam as a lever. But we do not distinctly

Strength of Materials. see what change this can produce in the mode of action of the fibres in this section, so as either to change their cohesion or the place of its centre of effort: yet something of this kind must happen.

We see indeed some circumstances which must contribute to make a smaller weight sufficient, in M. Buffon's experiments, to break a long beam, than in the exact inverse proportion of its length.

In the first place, the weight of the beam itself augments the strain as much as if half of it were added in the form of a weight. M. Buffon has given the weights of every beam on which he made experiments, which is very nearly seventy-four pounds per cubic foot. But they are much too small to account for the deviation from the theory. The half weights of the five-inch beams of seven, fourteen, and twenty-eight feet length, are only forty-five, ninety-two, and 182 pounds; which makes the real strains in the experiments 11,560, 5390, and 1956; which are far from having the proportions of four, two, and one.

Buffon says that healthy trees are universally strongest at the root end; therefore, when we use a longer beam, its middle point, where it is broken in the experiment, is in a weaker part of the tree. But the trials of the four-inch beams show that the difference from this cause is almost insensible.

The length must have some mechanical influence which the theory we have adopted has not yet explained. It may not however be inadequate to the task. The very ingenious investigation of the elastic curve by James Bernoulli and other celebrated mathematicians is perhaps as refined an application of mathematical analysis as we know. Yet in this investigation it was necessary, in order to avoid almost insuperable difficulties, to take the simplest possible case, viz. where the thickness is exceedingly small in comparison with the length. If the thickness be considerable, the quantities neglected in the calculus are too great to permit the conclusion to be accurate, or very nearly so. Without being able to define the form into which an elastic body of considerable thickness will be bent, we can say with confidence, that in an extreme case, where the compression in the concave side is very great, the curvature differs considerably from the Bernoullian curve. But as our investigation is incomplete and very long, we do not offer it to the reader. The following more familiar considerations will, we apprehend, render it highly probable that the relative strength of beams decreases faster than in the inverse ratio of their length. The curious observation by M. Buffon, of the vapour which issued with the hissing noise from the ends of a beam of green oak, while it was breaking by the load on its middle, shows that the whole length of the piece was affected: indeed it must be, since it is bent throughout. We have shown above, that a certain definite curvature of a beam of a given form is always accompanied by rupture. Now suppose the beam A of ten feet long, and the beam B of twenty feet long, bent to the same degree, at the place of their fixture in the wall; the weight which hangs on A is nearly double of that which must hang on B. The form of any portion, suppose five feet, of these two beams, immediately adjoining to the wall, is considerably different. At the distance of five feet the curvature of A is half of its curvature at the wall. The curvature of B in the corresponding point is three fourths of the same curvature at the wall. Through the whole of the intermediate five feet, therefore, the curvature of B is greater than that of A. This must make it weaker throughout. It must occasion the fibres to slide more on each other (that it may acquire this greater curvature), and thus affect their lateral union; and therefore those which are stronger will not assist their weaker neighbours. To this we must add, that in the shorter beams the force with which the fibres are pressed laterally on each other is double. This must impede the

Strength of Materials. mutual sliding of the fibres which we mentioned a little ago; nay, this lateral compression may change the law of longitudinal cohesion (as will readily appear to the reader who is acquainted with Boscovich's doctrines), and increase the strength of the very surface of fracture, in the same way (however inexplicable) as it does in metals when they are hammered or drawn into wire.

The reader must judge how far these remarks are worthy of his attention. The engineer will carefully keep in mind the important fact, that a beam of quadruple length, instead of having one fourth of the strength, has only about one sixth; and the philosopher should endeavour to discover the cause of this diminution, that he may give the artist a more accurate rule of computation.

We cannot discover the precise relation between the curvature and the momentum of cohesion. Our ignorance of the law by which the cohesion of the particles changes by a change of distance, hinders us from discovering the precise relation between the curvature and the momentum of cohesion; and all we can do is to multiply experiments, upon which we may establish some empirical rules for calculating the strength of solids. Those from which we must reason at present are too few and too anomalous to be the foundation of such an empirical formula. We may however observe, that M. Buffon's experiments gave us considerable assistance in this particular; for if to each of the numbers of the column for the five-inch beams, corrected by adding half the weight of the beam, we add the constant number 1245, we shall have a set of numbers which are very nearly reciprocals of the lengths. Let 1245 be called c , and let the weight which is known by experiment to be necessary for breaking the five-inch beam

of the length a be called P . We shall have $\frac{P+c \times a}{l} = c = p$.

Thus the weight necessary for breaking the seven-foot bar is 11,560. This added to 1245, and the sum multiplied by

7, gives $\frac{P+c \times a}{l} = 89,635$. Let l be 18; then $\frac{89,635}{18} - 1245$

$= 3725 = p$, which differs not more than $\frac{1}{40}$ th from what experiment gives us. This rule holds equally well in all the other lengths except the 10 and 24 feet beams, which are very anomalous. Such a formula is abundantly exact for practice, and will answer through a much greater variety of length, though it cannot be admitted as a true one; because, in a certain very great length, the strength will be nothing. For other sizes the constant number must change in the proportion of d^3 , or perhaps of p .

Relation between the strength and the square of the depth of the section. The next comparison which we have to make with the theory is the relation between the strength and the square of the depth of the section. This is made by comparing with each other the numbers in any horizontal line of the table. In making this comparison we find the numbers of the five-inch bars uniformly greater than the rest. We imagine that there is something peculiar to these bars; they are in general heavier than in the proportion of their section, but not so much so as to account for all their superiority. We imagine that this set of experiments, intended as a standard for the rest, has been made at one time, and that the season has had a considerable influence. The fact however is, that if this column be kept out, or uniformly diminished about one sixteenth in their strength, the different sizes will deviate very little from the ratio of the square of the depth, as determined by theory. There is however a small deficiency in the bigger beams.

We have been thus anxious in the examination of these experiments, because they are the only ones which have been related in sufficient detail, and made on a proper scale for giving us data from which we can deduce confidential maxims for practice. They are so troublesome and expensive that we have little hopes of seeing their number greatly increased; yet surely our navy board would do an

unspeakable service to the public by appropriating a fund for such experiments under the management of some man of science.

There remains another comparison which is of chief importance, namely, the proportion between the *absolute cohesion* and the *relative strength*. It may be guessed, from the very nature of the thing, that this must be very uncertain. Experiments on the absolute strength must be confined to very small pieces, by reason of the very great forces which are required for tearing them asunder. The values therefore deduced from them must be subject to great inequalities. Unfortunately we possess no detail of any experiments; all that we have to depend on are two passages of Muschenbroeck's *Essais de Physique*; in one of which he says, that a piece of sound oak $\frac{27}{100}$ ths of an inch square is torn asunder by 1150 pounds; and in the other, that an oak plank twelve inches broad and one thick will just suspend 189,163 pounds. These give for the cohesion of an inch square 15,755 and 15,763 pounds. Bouguer, in his *Traité du Navire*, says that it is very well known that a rod of sound oak one fourth of an inch square will be torn asunder by 1000 pounds. This gives 16,000 for the cohesion of a square inch. We shall take this as a round number, easily used in our computations. Let us compare this with M. Buffon's trials of beams four inches square.

The absolute cohesion of this section is $16,000 \times 16 = 256,000$. Did every fibre exert its whole force in the instant of fracture, the momentum of cohesion would be the same as if it had all acted at the centre of gravity of the section at two inches from the axis of fracture, and is therefore 512,000. The four-inch beam, seven feet long, was broken by 5312 pounds hung on its middle. The half of this, or 2656 pounds, would have broken it, if suspended at its extremity, projecting $3\frac{1}{2}$ feet, or 42 inches, from a wall. The momentum of this strain is therefore $2656 \times 42 = 111,552$. Now this is in equilibrio with the actual momentum of cohesion, which is therefore 111,552 instead of 512,000. The strength is therefore diminished in the proportion of 512,000 to 111,552, or very nearly of 4.59 to 1.

As we are quite uncertain as to the place of the centre of effort, it is needless to consider the full cohesion as acting at the centre of gravity, and producing the momentum 512,000; and we may convert the whole into a simple multiplier m of the length, and say, *as m times the length is to the depth, so is the absolute cohesion of the section to the relative strength*. Therefore let the absolute cohesion of a square inch be called f , the breadth b , the depth d , and the length l (all in inches), the relative strength, or the external force, p , which balances it, is $\frac{fbd^2}{9 \cdot 18l}$, or, in round numbers, $\frac{fbd^2}{9l}$; for $m = 2 \times 4.59$.

This great diminution of strength cannot be wholly accounted for by the inequality of the cohesive forces exerted in the instant of fracture; for in this case we know that the centre of effort is at one third of the height in a rectangular section (because the forces really exerted are as the extensions of the fibres). The relative strength would be $\frac{fbd^2}{3l}$, and p would have been 8127 instead of 2656.

We must ascribe this diminution (which is three times greater than that produced by the inequality of the cohesive forces) to the compression of the under part of the beam; and we must endeavour to explain in what manner this compression produces an effect which seems so little explicable by such means.

As we have repeatedly observed, it is a matter of nearly universal experience that the forces *actually* exerted by the

Strength of Materials.

Proportion between the absolute cohesion and the relative strength.

Strength of particles of bodies, when stretched or compressed, are very nearly in the proportion of the distances to which the particles are drawn from their natural positions. Now, although we are certain that, in enormous compressions, the forces increase faster than in this proportion, this makes no sensible change in the present question, because the body is broken before the compressions have gone so far; nay, we imagine that the compressed parts are crippled in most cases even before the extended parts are torn asunder. Muschenbroeck asserts this with great confidence with respect to oak, on the authority of his own experiments. He says, that although oak will suspend half as much again as fir, it will not support, as a pillar, two thirds of the load which fir will support in that form.

We imagine therefore that the mechanism in the present case is nearly as follows:

Let the beam $DC\Delta$ (fig. 21) be loaded at its extremity with the weight P , acting in the direction KP perpendicular to DC . Let $D\Delta$ be the section of fracture. Let DA be about one third of $D\Delta$. A will be the particle or fibre which is neither extended nor compressed. Make $\Delta\delta : D\delta = DA : A\Delta$. The triangles DAd , $\Delta A\delta$, will represent the accumulated attracting and repelling forces. Make AI and $Ai = \frac{1}{3} DA$ and $\frac{1}{3} \Delta A$. The point I will be that to which the full cohesion $D\delta$ or f of the particles in AD must be applied, so as to produce the same momentum which the variable forces at I , D , &c. really produce at their several points of application. In like manner, i is the circle of similar effort of the repulsive forces excited by the compression between A and Δ , and it is the real fulcrum of a bended lever IiK , by which the whole effect is produced. The effect is the same as if the full cohesion of the stretched fibres in AD were accumulated in I , and the full repulsion of all the compressed fibres in $A\Delta$ were accumulated in i . The forces which are balanced in the operation are the weight P , acting by the arm ki , and the full cohesion of AD acting by the arm Ii . The forces exerted by the compressed fibres between A and Δ only serve to give support to the lever, that it may exert its strain.

We imagine that this does not differ much from the real procedure of nature. The position of the point A may be different from what we have deduced from Buffon's experiments, compared with Muschenbroeck's value of the absolute cohesion of a square inch. If this last should be only 12,000, DA must be greater than we have here made it, in the proportion of 12,000 to 16,000. For Ii must still be made $= \frac{1}{3} A\Delta$, supposing the forces to be proportional to the extensions and compressions. There can be no doubt that a part only of the cohesion of $D\Delta$ operates in resisting the fracture in all substances which have any compressibility; and it is confirmed by the experiments of M. Duhamel on willow, and the inferences are by no means confined to that species of timber. We say, therefore, that when the beam is broken, the cohesion of AD alone is exerted, and that each fibre exerts a force proportional to its extension; and the accumulated momentum is the same as if the full cohesion of AD were acting by the lever $Ii = \frac{1}{3} d$ of $D\Delta$.

It may be said, that if only one third of the cohesion of oak be exerted, it may be cut two thirds through without weakening it. But this cannot be, because the cohesion of the whole is employed in preventing the lateral slide so often mentioned. We have no experiments to determine

that it may not be cut through one third without loss of its strength.

This must not be considered as a subject of mere speculative curiosity. It is intimately connected with all the practical uses which we can make of this knowledge; for it is almost the only way that we can learn the compressibility of timber. Experiments on the direct cohesion are indeed difficult, and exceedingly expensive if we attempt them in large pieces. But experiments on compression are almost impracticable. The most instructive experiments would be, first to establish, by a great number of trials, the transverse force of a moderate batten; and then to make a great number of trials of the diminution of its strength, by cutting it through on the concave side. This would very nearly give us the proportion of the cohesion which really operates in resisting fractures. Thus if it be found that one half of the beam may be cut on the under side without diminution of its strength (taking care to drive in a slice of harder wood), we may conclude that the point A is at the middle, or somewhat above it.

Much lies before the curious mechanician, and we are as yet very far from a scientific knowledge of the strength of timber.

In the mean time, we may derive from these experiments a useful rule, without relying on any value of the absolute cohesion of oak. We see that the strength is nearly as the breadth, as the square of the depth, and as the inverse of the length. It is most convenient to measure the breadth and depth of the beam in inches, and its length in feet. Since, then, a beam four inches square and seven feet between the supports is broken by 5312 pounds, we must conclude that a batten one inch square and one foot between the supports will be broken by 581 pounds. Then the strength of any other beam of oak, or the weight which will just break it when hung on its middle, is $581 \frac{bd^2}{l}$.

But we have seen that there is a very considerable deviation from the inverse proportion of the lengths, and we must endeavour to accommodate our rule to this deviation. We found, that by adding 1245 to each of the ordinates or numbers in the column of the five-inch bars, we had a set of numbers very nearly reciprocal of the lengths; and if we make a similar addition to the other columns in the proportion of the cubes of the sixes, we have nearly the same result. The greatest error (except in the case of experiments which are very irregular) does not exceed $\frac{1}{15}$ th of the whole. Therefore, for a radical number, add to the 5312 the number 640, which is to 1245 very nearly as 4^3 to 5^3 . This gives 5952. The 64th of this is 93, which corresponds to a bar of one inch square and seven feet long. Therefore 93×7 will be the reciprocal corresponding to a bar of one foot. This is 651. Take from this the present empirical correction, which is $\frac{b \ 40}{b \ 4}$, or 10, and there remains 641 for the strength of the bar. This gives us for a general rule $p = 651 \frac{bd^2}{l} \div 10 \ bd^2$.

Example. Required the weight necessary to break an oak beam eight inches square and twenty feet between the props, $p = 651 \times \frac{8 \times 8^2}{20} \div 10 \times 8 \times 8^2$. This is 11,545, whereas the experiment gives 11,487. The error is very small indeed. The rule is most deficient in comparison with the five-inch bars, which, we have already said, appear stronger than the rest.

The following process is easily remembered by such as are not algebraists.

Multiply the breadth in inches twice by the depth, and

Strength of Materials.

A useful rule may be deduced from M. Buffon's experiments.

Strength of Materials. call this product f . Multiply f by 651, and divide by the length in feet. From the quotient take 10 times f . The remainder is the number of pounds which will break the beam.

We are not sufficiently sensible of our principles to be confident that the correction $10f$ should be in the proportion of the section, although we think it most probable. It is quite empirical, founded on Buffon's experiments. Therefore the safe way of using this rule is to suppose the beam square, by increasing or diminishing its breadth till equal to the depth. Then find the strength by this rule, and diminish or increase it for the change which has been made in its breadth. Thus, there can be no doubt that the strength of the beam given as an example is double of that of a beam of the same depth and half the breadth.

The reader cannot but observe that all this calculation relates to the very greatest weight which a beam will bear for a very few minutes. M. Buffon uniformly found that two thirds of this weight sensibly impaired its strength, and frequently broke at the end of two or three months. One half of this weight brought the beam to a certain bend, which did not increase after the first minute or two, and may be borne by the beam for any length of time. But the beam contracted a bend, of which it did not recover any considerable portion. One third seemed to have no permanent effect on the beam; but it recovered its rectilinear shape completely, even after having been loaded several months, provided that the timber was seasoned when first loaded; that is to say, one third of the weight which would quickly break a seasoned beam, or one fourth of what would break one just felled, may lie on it for ever without giving the beam a set.

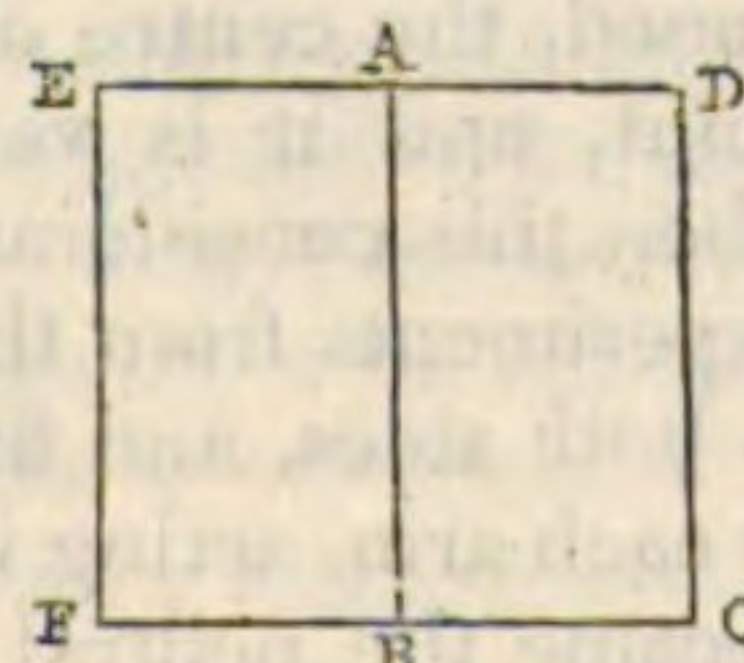
We have no detail of experiments on the strength of other kinds of timber: only M. Buffon says, that fir has about $\frac{6}{10}$ ths of the strength of oak; Mr Parent makes it $\frac{10}{12}$ ths; Emerson, $\frac{2}{3}$ ds, &c.

We have been thus minute in our examination of the mechanism of this transverse strain, because it is the greatest to which the parts of our machines are exposed. We wish to impress on the minds of artists the necessity of avoiding this as much as possible. They are improving in this respect, as may be seen by comparing the centres on which stone arches of great span are now turned with those of former times. They were formerly a load of mere joists resting on a multitude of posts, which obstructed the navigation, and were frequently losing their shape by some of the posts sinking into the ground. Now they are more generally trusses, where the beams abut on each other, and are relieved from transverse strains. But many performances of eminent artists are still very injudiciously exposed to cross strains. We may instance one which is considered as a fine work, viz. the bridge at Walton on Thames. Here every beam of the great arch is a joist, and it hangs together by framing. The finest piece of carpentry that we have seen is the centre employed in turning the arches of the bridge at Orleans, described by Perronet. In the whole there is not one cross strain. The beam, too, of Hornblower's steam-engine is very scientifically constructed.

Strain produced by twisting. IV. The last species of strain which we are to examine is that produced by twisting. This takes place in all axles which connect the working parts of machines.

The resistance must be proportional to the number of particles. Although we cannot pretend to have a very distinct conception of that modification of the cohesion of a body by which it resists this kind of strain, we can have no doubt that, when all the particles act alike, the resistance must be proportional to the number. Therefore if we suppose the two parts ABCD, ABFE (fig. 22), of the body EFCD to be of insuperable strength, but cohering more weakly in the common surface

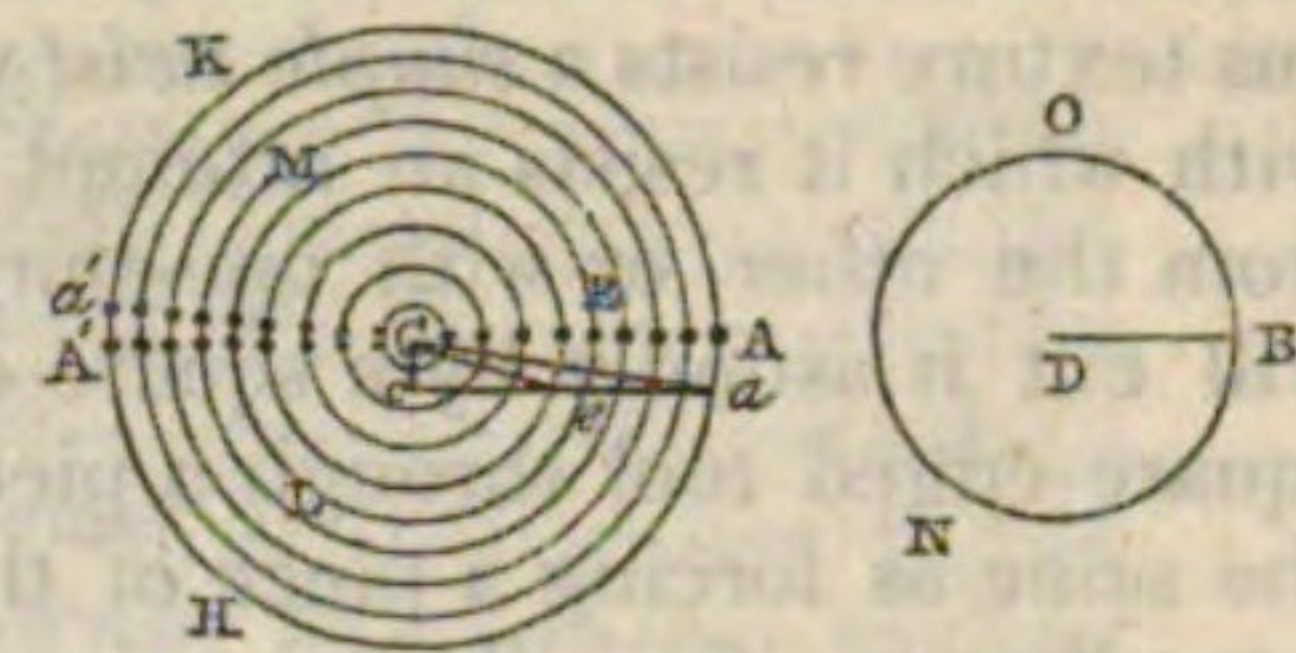
Fig. 22.



AB, and that one part ABCD is pushed laterally in the direction AB, there can be no doubt that it will yield only there, and that the resistance will be proportional to the surface.

In like manner, we can conceive a thin cylindrical tube, of which KAH (fig. 23) is the section, as cohering more weakly in that section than anywhere else. Suppose it to be grasped in both hands, and the two parts twisted round the axis in opposite directions, as we would twist the joints of a flute; it is plain

Fig. 23.



that it will first fail in this section, which is the circumference of a circle, and the particles of the two parts which are contiguous to this circumference will be drawn from each other laterally. The total resistance will be as the number of equally resisting particles, that is, as the circumference (for the tube being supposed very thin, there can be no sensible difference between the dilatation of the external and internal particles). We can now suppose another tube within this, and a third within the second, and so on till we reach the centre. If the particles of each ring exerted the same force (by suffering the same dilatation in the direction of the circumference), the resistance of each ring of the section would be as its circumference and its breadth (supposed indefinitely small), and the whole resistance would be as the surface; and this would represent the resistance of a solid cylinder. But when a cylinder is twisted in this manner by an external force applied to its circumference, the external parts will suffer a greater circular extension than the internal; and it appears that this extension (like the extension of a beam strained transversely) will be proportional to the distance of the particles from the axis. We cannot say that this is demonstrable, but we can assign no proportion that is more probable. This being the case, the forces simultaneously exerted by each particle will be as its distance from the axis. Therefore the whole force exerted by each ring will be as the square of its radius, and the accumulated force actually exerted will be as the cube of the radius; that is, the accumulated force exerted by the whole cylinder, whose radius is CA, is to the accumulated force exerted at the same time by the part whose radius is CE, as CA^3 to CE^3 .

The whole cohesion now exerted is just two thirds of what it would be if all the particles were exerting the same attractive forces which are just now exerted by the particles in the external circumference. This is plain to any person in the least familiar with the fluxionary calculus. But such as are not may easily see it in this way.

Let the rectangle ACca be set upright on the surface of the circle along the line CA, and revolve round the axis Cc. It will generate a cylinder whose height is Cc or Aa, and having the circle KAH for its base. If the diagonal Ca be supposed also to revolve, it is plain that the triangle cCa will generate a cone of the same height, and having for its base the circle described by the revolution of ca, and the point C for its apex. The cylindrical surface generated by Aa will express the whole cohesion exerted by the circumference AHK, and the cylindrical surface generated by Ee will represent the cohesion exerted by the circumference ELM, and the solid generated by the triangle CAa will represent the cohesion exerted by the whole circle AHK, and the cylinder generated by the rectangle ACca will represent the cohesion exerted by the same surface if each particle had suffered the extension Aa.

Now it is plain, in the first place, that the solid generated by the triangle eEC is to that generated by aAC as EC^3 to

Strength of AC^3 . In the next place, the solid generated by aAC is two thirds of the cylinder, because the cone generated by cCa is one third of it.

We may now suppose the cylinder twisted till the particles in the external circumference lose their cohesion. There can be no doubt that it will now be wrenched asunder, all the inner circles yielding in succession. Thus we obtain one useful information, viz. that a body of homogeneous texture resists a *simple twist* with two thirds of the force with which it resists an attempt to force one part laterally from the other, or with one-third part of the force which will cut it asunder by a square-edged tool; for to drive a square-edged tool through a piece of lead, for instance, is the same as forcing a piece of the lead as thick as the tool laterally away from the two pieces on each side of the tool. Experiments of this kind do not seem difficult, and they would give us very useful information.

When two cylinders AHK and BNO are wrenched asunder, we must conclude that the external particles of each are just put beyond their limits of cohesion, are equally extended, and are exerting equal forces. Hence it follows, that in the instant of fracture the sum-total of the forces actually exerted are as the squares of the diameters.

For drawing the diagonal Ce , it is plain that $Ee = Aa$ expresses the distension of the circumference ELM, and that the solid generated by the triangle CEe expresses the cohesion exerted by the surface of the circle ELM, when the particles in the circumference suffer the extension Ee equal to Aa . Now the solids generated by CAa and CEe being respectively two thirds of the corresponding cylinders, are as the squares of the diameters.

Having thus ascertained the real strength of the section, and its relation to its absolute lateral strength, let us examine its strength relative to the external force employed to break it. This examination is very simple in the case under consideration. The straining force must act by some lever, and the cohesion must oppose it by acting on some other lever. The centre of the section may be the neutral point, whose position is not disturbed.

Let F be the force exerted laterally by an exterior particle. Let a be the radius of the cylinder, and x the indeterminate distance of any circumference, and dx the indefinitely small interval between the concentric arches; that is, let dx be the breadth of a ring and x its radius. The forces being as the extensions, and the extensions as the distances from the axis, the cohesion actually exerted at any part of

any ring will be $f \frac{xdx}{a}$. The force exerted by the whole

ring (being as the circumference or as the radius) will be $f \frac{x^2 dx}{a}$. The momentum of cohesion of a ring, being as

the force multiplied by its lever, will be $f \frac{x^3 dx}{a}$. The accu-

mulated momentum will be the sum or fluent of $f \frac{x^3 dx}{a}$;

that is, when $x = a$, it will be $\frac{1}{4} f \frac{a^4}{a} = \frac{1}{4} fa^3$.

Hence we learn that the strength of an axle, by which it resists being wrenched asunder by a force acting at a given distance from the axis, is as the cube of its diameter.

But, further, $\frac{1}{4} fa^3$ is $= fa^2 \times \frac{1}{4} a$. Now fa^2 represents the full lateral cohesion of the section. The momentum therefore is the same as if the full lateral cohesion were accumulated at a point distant from the axis by one fourth of the radius, or one eighth of the diameter of the cylinder.

Therefore let F be the number of pounds which measure the lateral cohesion of a circular inch, d the diameter of the cylinder in inches, and l the length of the lever by which

the straining force p is supposed to act; we shall have $F \times \frac{1}{8} d^3 = pl$, and $F \frac{d^3}{8l} = p$.

We see in general that the strength of an axle, by which it resists being wrenched asunder by twisting, is as the cube of its diameter.

We see also that the internal parts are not acting so powerfully as the external. If a hole be bored out of the axle of half its diameter, the strength is diminished only one eighth, while the quantity of matter is diminished one fourth. Therefore hollow axles are stronger than solid ones containing the same quantity of matter. Thus let the diameter be 5, and that of the hollow 4; then the diameter of another solid cylinder having the same quantity of matter with the tube is 3. The strength of the solid cylinder of the diameter 5 may be expressed by 5^3 , or 125. Of this the internal part (of the diameter 4) exerts 64; therefore the strength of the tube is $125 - 64 = 61$. But the strength of the solid axle of the same quantity of matter and diameter 3 is 3^3 , or 27, which is not half of that of the tube.

Engineers, therefore, have of late introduced this improvement in their machines, and the axles of cast iron are all made hollow when their size will admit of it. They have the additional advantage of being much stiffer, and of affording much better fixture for the flanches which are used for connecting them with the wheels or levers by which they are turned and strained. The superiority of strength of hollow tubes over solid cylinders is much greater in this kind of strain than in the former or transverse. In this last case the strength of this tube would be to that of the solid cylinder of equal weight as 61 to 32 and a half nearly.

The apparatus which we mentioned on a former occasion for trying the lateral strength of a square inch of solid matter, enabled us to try this theory of twist with all desirable accuracy. The bar which hung down from the pin in the former trials was now placed in a horizontal position, and loaded with a weight at the extremity. Thus it acted as a powerful lever, and enabled us to wrench asunder specimens of the strongest materials. We found the results perfectly conformable to the theory, in as far as it determined the proportional strength of different sizes and forms; but we found the ratio of the resistance to twisting to the simple lateral resistance considerably different, and it was some time before we discovered the cause.

We had here taken the simplest view that is possible of the action of cohesion in resisting a twist. It is frequently exerted in a very different way. When, for instance, an iron axle is joined to a wooden one by being driven into one end of it, the extensions of the different circles of particles are in a very different proportion. A little consideration will show that the particles in immediate contact with the iron axle are in a state of violent extension; so are the particles of the exterior surface of the wooden part, and the intermediate parts are less strained. It is almost impossible to assign the exact proportion of the cohesive forces exerted in the different parts. Numberless cases can be pointed out where parts of the axle are in a state of compression, and where it is still more difficult to determine the state of the other particles. We must content ourselves with the deductions made from this simple case, which is fortunately the most common. In the experiments just now mentioned, the centre of the circle is by no means the neutral point, and it is very difficult to ascertain its place; but when this consideration occurred to us, we easily freed the experiments from this uncertainty, by extending the lever to both sides, and by means of a pulley applied equal force to each arm, acting in opposite directions. Thus the centre became the neutral point, and the resistance to twist was found to be two thirds of the simple lateral strength.

We beg leave to mention here, that our success in these

Strength of Materials.

Hollow axles more proper than solid ones

and now generally used.

The ratio of resistance to twisting to the simple lateral resistance appears different.

But when the experiment was altered, it was exactly the same.

Stretching experiments encouraged us to extend them much farther. We hoped by these means to discover the absolute cohesion of many substances, which would have required an enormous apparatus and a most unmanageable force to tear them asunder directly. But we could reason with confidence from the resistance to twist (which we could easily measure), provided that we could ascertain the proportion of the direct and the lateral strengths. Our experiments on chalk, finely prepared clay, and white bee's wax (of one melting and one temperature), were very consistent and satisfactory. But we have hitherto found great irregularities in this proportion in bodies of a fibrous texture like timber. These are the most important cases, and we still hope to be able to accomplish our project, and to give the public some valuable information. This being our sole object, it was our duty to mention the method which promises success, and thus excite others to the task; and it will be no mortification to us to be deprived of the honour of being the first who thus adds to the stock of experimental knowledge.

Experiments on chalk, clay, and wax, satisfactory; but those on timber irregular.

When the matter of the axle is of the most simple texture, such as that of metals, we do not conceive that the length of the axle has any influence on the fracture. It is otherwise if it be of a fibrous texture like timber; the fibres are bent before breaking, being twisted into spirals like a cork-screw. The length of the axle has somewhat of the influence of a lever in this case, and it is easier wrenched asunder if long. Accordingly we have found it so; but we have not been able to reduce this influence to calculation.

Many useful deductions might be made from these premises respecting the manner of disposing and combining the strength of materials in our structures. The best form of joints, mortises, tenons, scarphs, the rules for joggling, tabling, faying, fishing, &c. practised in the delicate art of mast-making, are all founded on this doctrine; but the discussion of these would be equivalent to writing a complete treatise of carpentry.

(B. B. B.)

STRETCHING, in *Navigation*, is generally understood to imply the progression of a ship under a great surface of sail, when close-hauled.

STRETTA (Ital.), a musical term, often applied to the last allegro of a finale, &c. in an opera. It signifies also a kind of peroration or winding up of a piece of music, particularly of a fugue. See *Music*.

STRETTO, or *più Stretto* (Ital.), indicates an acceleration of the time of a piece of music.

STRIATED LEAF, among botanists, one that has a number of longitudinal furrows on its surface.

STRIKE, a measure of capacity, containing four bushels. Also an instrument used in measuring corn.

STROMBOLI, the most northern island of the Lipari group, in the Mediterranean, being a part of the kingdom of Naples. It was known to the ancients by the name of Strongyle; a name implying a conical mountain with an irregular base. The mountain is bifurcated, upwards of 2000 feet in height, and about nine miles in circumference, and is evidently a monstrous product of subterranean fires. The crater of this mountain is on the north-west side, about two thirds of the whole height from the base; it is of a circular form, and about one hundred and seventy yards in diameter, and has a yellow efflorescence adhering to its sides, as to those of Mount *Ætna*. This crater has burnt without intermission from the earliest periods, and is supposed to be supported by oxygen, pyrites, and sulphur; but there are not any traces of the aid of bitumen. It appears to be not only the vent of all these islands, but likewise to have subterraneous communication with Sicily and Italy; for, previously to a severe earthquake taking place in those parts, Stromboli has been observed to be covered with dense clouds of smoke, and to emit with increased activity unusually ardent

The most recent experiments on the strength and elasticity of material give the results entered in the following tables.

TABLE I.—*Distensions of Rods for a Strain of one Pound per Square Inch; computed from the results given in Tredgold, edition of 1840, as deduced from observations on transverse strain.*

British timber.....	Oak.....	92000
	Larch.....	86000
	Scotch fir.....	80000
	Ash.....	120000
Foreign timber.....	Memel fir.....	73000
	Norway fir.....	109000
	American pine.....	50000
	White spruce.....	92000
	Riga oak.....	100000
English malleable iron.....		2420000

TABLE II.—*Cohesive Strengths of Bars per Square Inch.*

	lbs.	lbs.
Oak.....	from 14,000 to	19,000
Beech.....	from 11,000 to	22,000
Ash.....	from 12,000 to	17,000
Elm.....	from 13,000 to	14,000
Mahogany.....	from 8,000 to	21,000
Teak.....	from 8,000 to	15,000
Pine (Norway).....	from 7,000 to	14,000
Larch.....	from 9,000 to	10,000
Iron wire.....	from 94,000 to	113,000
Swedish iron.....	from 53,000 to	78,000
English iron.....	from 55,000 to	66,000
Cast iron.....	from 16,000 to	33,000

flames. The access to the summit, though fatiguing, is not dangerous. When a person approaches the crater, and the smoke clears away, as it does at intervals, he can observe an undulating igneous substance, which at short periods rises and falls with great agitation, and when swollen to the utmost height bursts with a violent explosion and a discharge of red-hot stones in a semi-fluid state, accompanied with showers of ashes, and a strong sulphureous smell. These masses are thrown up to the height of from sixty or seventy to three hundred feet, and some few even to a thousand. In the moderate ejections the stones in their ascent gradually diverge like a grand pyrotechnical exhibition, and fall again into the abyss, except on the side next the sea, where they roll down in quick succession to the water.

The island contains about 1200 inhabitants. The principal places are St Bartolo and St Vincenzo. The soil is a black mold, very fertile, consisting of argillaceous tufa, scorix, puzzolana, and sand. Stromboli produces some good wine, with excellent wheat, barley, cotton, rasins, currants, and figs. The church of St Bartolo is in long. 15. 13. 10. E., and lat. 38. 48. 12. N.

STROMNESS, a town in the parish of the same name in the island of Pomona, Orkney, in long. 3. 38. W. and lat. 58. 58. N. The town is situated on the western side of the island, and was formerly an insignificant village, dependent on the borough of Kirkwall, which kept it completely under; but by a decision of the House of Lords, Stromness and all other villages were declared free from being assessed, and otherwise independent of royal boroughs. The present town consists of one long rambling street, built round the bay on which it is placed. The greater portion of the houses are built so close on the water that they require to be defended by bulwarks, jetties, and quays, to keep them from being overwhelmed by

Strophe
||
Strype.

the sea. At these small vessels load and unload. The harbour is formed by the bay, which is about a mile in length, and half of that in breadth. It forms one of the most secure harbours in the north of Scotland, and affords safe anchorage for vessels of 1000 tons burden; and it is the chief resort for shipping in the northern isles. The wealth of the inhabitants is chiefly derived from the Greenland whalers, which touch here to complete their crews from the sailors belonging to the place, as well as to supply the vessels with provisions and stores. The Hudson Bay vessels also touch here. A number of ships and boats are built at Stromness; and the manufacture of straw-plait is carried on to a considerable extent. It was erected into a borough of barony in the year 1817, and it is governed by two bailies and nine councillors. The population in 1831 amounted to 2182.

STROPHE, in ancient poetry, a certain number of verses, including a perfect sense, and making the first part of an ode.

STROUD, a town of the hundred of Shamwell, in the lathe of Aylesford and county of Kent, twenty-nine miles from London. It stands on the river Medway, over which is a bridge connecting it with Rochester, so as in appearance to make it merely a suburb to that city. It consists of a single long street. The church is a fine old building, which formerly belonged to the Knights Templars, who had a palace near this town. The ruins of it are still visible on the banks of the river. The inhabitants amounted in 1801 to 1172, in 1811 to 1394, in 1821 to 1461, and in 1831 to 1549.

STROUD, a town in the hundred of Bisley and county of Gloucester, 102 miles from London. It stands on a hill near the Stroud water, which empties itself into the Severn. The Stroud is brought into communication with the Thames by means of a canal. It is a considerable clothing town, especially esteemed for the excellence of its dark-blue cloths. It was created a borough by the act of 1832, and returns two members to the House of Commons. It has a well-frequented market on Friday. The inhabitants amounted in 1801 to 5422, in 1811 to 5321, in 1821 to 7097, and in 1831 to 8607.

STRYPE, JOHN, a most industrious and meritorious labourer in the department of ecclesiastical and literary history, was born at Stepney on the first of November 1643. His father, John van Stryp, was a native of Brabant, and sought refuge in England on account of his religion. He was a merchant and silk-thrower. The son received his early education at St Paul's school, where he remained for six years. In 1662 he proceeded to Jesus College, Cambridge, from which he was transferred to Catherine Hall. In 1665, he there took the degree of A.B., and that of A.M. four years afterwards. He was appointed to the perpetual curacy of Theydon-Boys, in the county of Essex, in 1669; but he only retained it for a few months, having been appointed minister of Low Leyton, in the same county. He was elected by the parishioners, whom the patrons had left to make their own choice of a spiritual guide. His emoluments were not secured to him in the usual way, but by a bond for his maintenance entered into by his parishioners. Their annual subscriptions amounted to sixty-nine pounds sterling. Five years after his appointment to that parish, he was licensed by the bishop of London to preach the word of God in Low Leyton; and the bishop's license was the only credential which he had to produce. This undisturbed enjoyment of questionable rights may be attributed to the favour which the ecclesiastical dignitaries felt for a man who had made many valuable additions to the annals of the church. When far advanced in life, Strype was presented by Archbishop Tenison to the sinecure of Terring in Sussex. He was also appointed to the lectureship of Hackney, which he resigned in 1724. At Hackney he resided, in his old age, under the roof of Mr Harris, an apothecary, who was mar-

ried to his grand-daughter. In his house he died on the 11th of December 1737, at the patriarchal age of ninety-four.

Strype's principal works are, *The Life of Archbishop Cranmer*, 1694, fol.: *The Life of Sir Thomas Smith*, 1698, 8vo: *The Life of Dr John Aylmer*, bishop of London, 1701, 8vo: *The Life of Sir John Cheke*, 1705, 8vo: *Annals of the Reformation*, 4 vols.; vol. i. 1709, reprinted 1725; vol. ii. 1725; vol. iii. 1728; vol. iv. 1731: *The Life of Archbishop Grindal*, 1710, fol.: *The Life and Letters of Archbishop Parker*, 1711, fol.: *The Life of Archbishop Whitgift*, 1718, fol.: *Ecclesiastical Memorials*, 1721, 3 vols. fol.

The writings of Strype were for many years neglected, but they are now held in deserved estimation; and they have all been reprinted at the Clarendon press. He is not remarkable for the methodical arrangement of his materials, nor did he ever attain to much proficiency in the art of composition; but no one ever denied him the praise of diligence and fidelity. Beside these works, he published *Lessons for Youth and Old Age*, 1699, 12mo. He likewise published the second volume of *Dr Lightfoot's Works*, in 1684; and an elaborate edition of *Stow's Survey of London*, 1720, 2 vols. fol.

STUART, GILBERT, an eminent jurist and historian, was born at Edinburgh in the year 1742. His father, George Stuart, LL. D., had succeeded John Ker as professor of humanity during the preceding year. According to the tradition of the university, he was an excellent Latinist, but of his proficiency he has left no public proofs. He had prepared an amended and enlarged edition of *Ainsworth's Latin Dictionary*; but it was never committed to the press, and its suppression may perhaps have been occasioned by the too high estimate which the professor had formed of its pecuniary value.

The son was educated in the public school and in the university of his native city. Of his proficiency in several branches of study, his various works afford a sufficient criterion. To the pursuit of jurisprudence he devoted himself with uncommon ardour; but although he had a strong relish for law as a science, he anticipated no delight from its practice, and he was never called to the bar. Of his early progress in this study he exhibited a very conspicuous specimen in a work published without his name; "*An Historical Dissertation concerning the Antiquity of the English Constitution*." Edinb. 1768, 8vo. It has been asserted that when he produced this work, he was little more than twenty years of age; but the statement is not sufficiently accurate, for he had then attained his twenty-sixth year. For a writer of that age, or indeed of any age, it is an ingenious and able performance. His chief favourites and models are Tacitus and Montesquieu. With no mean talents for research and disquisition, he has endeavoured to evince that "the parts which compose our constitution arose more immediately from the forests of Germany." The same ground had recently been occupied by the learned Dr Squire, bishop of St David's; of whose *Inquiry into the Foundation of the English Constitution* a second edition appeared in the year 1753. Stuart's *Dissertation*, distinguished by so much vigour of intellect and maturity of juridical learning, procured him from the university the degree of LL. D., which is very rarely bestowed upon so young a scholar. A second edition, bearing the author's name, was published at London in the year 1771, and he then prefixed a dedication to the earl of Mansfield.

The dedication is dated at London in the month of January 1770; and before this period he had become a regular contributor to the *Monthly Review*, with which he continued his connexion from 1768 to 1774. We likewise find him employed as the editor of "*An Historical Treatise on the Feudal Law, and the Constitution and Laws of England*;" with a *Commentary on Magna Charta*, and necessary *Illustrations of many of the English Statutes*: in a

Stuart.

Stuart. Course of Lectures read in the University of Dublin, by the late Francis Stoughton Sullivan, LL. D., Royal Professor of the Common Law in that University." Lond. 1772, 4to. Dr Sullivan had obtained a fellowship at the early age of nineteen; and, as his editor informs us, he "was not less remarkable for his knowledge in history and chronology than for his skill in his profession as a barrister and civilian." Towards the close of his life, he was engaged in preparing a History of Ireland; but this task was reserved for Dr Leland, another distinguished fellow of Trinity College. The editor, whose name does not appear, has prefixed a preface of four pages, and has particularly extolled the author for his "admirable vindication of the original freedom of our constitution, and his excellent commentary on *Magna Charta*."

A pseudonymous work, of a very different denomination, has been ascribed to Dr Stuart. It bears the title of "Animadversions on Mr Adam's Latin and English Grammar; being an Exhibition of its Defects, and an Illustration of the Danger of Introducing it into Schools. By John Richard Busby, Master of Arts." Edinb. 1773, 8vo. This grammar, at its first appearance, was doomed to encounter a very fierce and general opposition. The other four masters of the school to which the author belonged, presented to the town-council a remonstrance against it; and the use of it in that seminary was formally prohibited.¹ Stuart's zeal might be excited by his relationship to Ruddiman, whose elementary works, both excellent in their kind, had for half a century retained their place in the grammar schools. That the writer has detected and specified errors and omissions, it would not be safe to deny; but the spirit as well as the style of his animadversions is such as no unprejudiced reader could approve. They conclude with the subsequent passage: "These strictures will, it is thought, be sufficient to evince the entire frivolity of Mr Adam's grammar, and the danger that must attend its adoption into our schools. To point out all the errors of his performance, would require several volumes; and I am not ambitious of performing a task that would vie with any of the labours of Hercules. It is the peculiar infelicity of this grammarian, that he exhibits every defect which it is possible for an author to possess; a sterile invention, an unhappy method, a cold and inauspicious manner, an inaccurate and nerveless expression, a perverted judgment, a defective understanding, a corrupted taste.—Education is not a matter to be trifled with. The mistakes and mis-carriage of our most generous youth have too frequently their rise in the negligence with which they have been treated in schools, where they have been sent to be initiated in the first principles of knowledge. It is also no groundless complaint, that the teacher often adds incapacity to neglect. And if this is, in general, a just representation of the matter, how must we pity, in particular, the pupils of Mr Adam! To disadvantages common to other boys, they must join the cruel and insuperable one of studying a work that advances in an unvaried progress from blunder to blunder, and from absurdity to absurdity." The merits and demerits of this grammar, which in spite of all opposition became very popular, were discussed in various articles of the *Weekly Magazine*. Here we find two Latin lucubrations on the subject, one of which was known to be the production of Stuart, and the other might perhaps be written by the same satirical pen. In the form of a description of a Roman funeral, he records the interment of Adam's Latin Grammar; nor does he neglect to introduce the well-known Jamie Duff, an idiot whose supreme delight was to place himself, an unhired attendant, at the head of a funeral pro-

cession: "Imus ad hortos scholasticos, præeunte Jacobo Stuart. Duff, solita sua gravitate, densissimo ac lætissimo puerorum agmine cincto." The narrative closes with this monumental inscription:

In hac urna jacet quod reliquum est
 Libelli inauspicati,
 nunquam resurrecturi,
 invita et irata Minerva editi;
 qui miserabiliter
 in tenera ætate raptus,
 triste præbet exemplum
 fragilitatis humanæ,
 nec non vanitatis auctorum,
 qui Musis non rite litantes
 longiorem expectant vitam.
 Siste viator; et, si meliorem animæ partem
 velis esse superstitem,
 fatum meum tecum reputa.
 Festina lentius, et vale.²

Dr Stuart now undertook the management of "The Edinburgh Magazine and Review," of which the first number bears the date of November 1773. In the commercial part of this enterprise his partners were Alexander Kincaid, his majesty's printer, William Creech, bookseller, William Smellie, printer, and William Kerr, surveyor of the post-office. The work was printed by Smellie, who was likewise to manage the business details of the concern, to furnish the last half-sheet of every number, and to review such books as the editor and he should select. The profits were to be distributed into six shares; one of which was allotted to Kincaid and Creech conjunctly; one each to Stuart, Smellie, and Kerr; and the remaining two to the editor and the printer, to be divided between them as they should mutually agree. Stuart was himself the principal writer. Various essays and reviews were furnished by Smellie. Lord Hailes, Dr Blacklock, Professor Richardson of Glasgow, and Professor Barron of St Andrews, were among the number of the contributors. The name of Dr Moor appears in the poetical department. An extraordinary lucubration, entitled "A modest Defence of the Accomplishment of Blasphemy," was written by the Rev. A. Gillies. The Rev. Mr Nimmo of Bothkennar wrote the Essay on the Antiquities of Stirlingshire, which he afterwards enlarged to the size of an octavo volume.³

A periodical work, supported by such contributors, might have run a long and prosperous career, if its success had not been marred by the editor's want of temper and discretion. At that period, the population of Edinburgh probably did not amount to one third of its present number; and the freedom of public discussion was circumscribed in at least an equal proportion. Dr Henry was one of those who had most reason to complain of injurious treatment. A single sermon of his was very unfavourably noticed by Smellie; and on the second volume of his History of Great Britain two articles were written by Stuart, in a style of unmitigated sarcasm and contempt; nor does it appear that there was any original ground of personal offence. In some fragments of his letters which have been published by D'Israeli, he speaks of this historian with a strange mixture of levity and virulence. Lord Monboddo did not experience better treatment. On the second volume of his Origin and Progress of Language they inserted two, and on the third volume three articles, each of them more offensive than another. These articles were written by Stuart, Smellie, and Gillies, but the greater portion of them by the latter. The editor lent his aid in the review of the third

¹ Henderson's Account of the Life and Character of Alexander Adam, LL. D. Rector of the High School of Edinburgh, p. 42. Edinb. 1810, 8vo.

² *Weekly Magazine*, vol. xix. p. 245. See likewise p. 53.

³ Kerr's Memoirs of Smellie, vol. i. p. 401.

Stuart. volume, and in the art of vituperation he greatly excelled his coadjutors. It is scarcely to be supposed that any of the disparaging expressions were attributable to Smellie. This attack on the learned judge gave great offence to him and his friends, and indeed it had a visible effect in precipitating the failure of the work. Of Lord Kames's Sketches of the History of Man the editor had prepared a very severe review; but when it was sent to the printer, he "counteracted the intentions of his colleague, by altering the whole into a totally opposite tendency, converting the far greater part from harsh invective into reasonable and merited panegyric." On discovering that the venom had thus been extracted, the writer was moved with violent anger; but he speedily moderated his feelings so far as to admit that his friend had acted rightly. Smellie, though he generally exercised a sounder discretion, could himself display a strong vein of satire. This remark was sufficiently verified in his controversy with Dr Nisbet, then minister of Montrose, and afterwards president of Dickinson College at Carlisle in Pennsylvania.¹ The controversy was occasioned by the mode of reporting a certain debate in the General Assembly. Nisbet printed two letters in a newspaper, and Smellie replied in the magazine. This publication was continued till the month of August 1776, when it terminated with the fifth volume. A closing notice informed the "numerous and respectable encouragers of this work," that its publication was only interrupted for some months, and that it would afterwards appear in an improved form. But the promise was never fulfilled, nor is it very probable that many readers expected its fulfilment.

Notwithstanding the failure of this project, Dr Stuart had displayed so much talent in his principal articles, that his reputation as a man of letters suffered no diminution. He however felt a very painful mortification at the unsuccessful result of his labours; and his mind was so badly regulated that, instead of reflecting on the natural tendency of his own conduct, he continued to cherish a most bitter and indiscriminate resentment. In a letter, dated on the 17th of June 1774, and probably addressed to his London publisher, he expresses himself in these unseemly terms: "It is an infinite disappointment to me, that the Magazine does not grow in London; I thought the soil had been richer. But it is my constant fate to be disappointed in every thing I attempt; I do not think I ever had a wish that was gratified, and never dreaded an event that did not come. With this felicity of fate, I wonder how the devil I could turn projector. I am now sorry that I left London; and the moment that I have money enough to carry me back to it, I shall get off. I mortally detest and abhor this place, and every body in it. Never was there a city where there was so much pretension to knowledge, and that had so little of it. The solemn foppery, and the gross stupidity of the Scottish literati, are perfectly insupportable. I shall drop my idea of a Scots newspaper. Nothing will do in this country that has common sense in it; only cant, hypocrisy, and superstition, will flourish here. A curse on the country, and all the men, women, and children of it.... The publication is too good for the country. There are very few men of taste or erudition on this side the Tweed; yet every idiot one meets with lays claim to both. Yet the success of the Magazine is in reality greater than we could expect, considering that we have every clergyman in the kingdom to oppose it; and that the magistracy of the place are every moment threatening its destruction." All this exhibits a melancholy picture of a man of superior talents and attainments, deriving no wisdom from experience, but still indulging those very passions to which his want of success was chiefly to be attributed, and which al-

ways bear along with them their own punishment. Before he vented his spleen in terms of such unseemly import, he ought to have recollected, "It is a foul *corby* that bewrays its own nest." The fault that he here commits, is not one with which his countrymen are commonly chargeable; and the period which he thus describes as so barren in taste and erudition, was perhaps remarkable for its intellectual eminence beyond any former or succeeding period in the literary annals of Scotland.

Dr Stuart was still in the early vigour of manhood, and he speedily roused himself to new and greater exertions. After an interval of less than two years, he produced what we are disposed to regard as the best of his works, "A View of Society in Europe, in its Progress from Rudeness to Refinement: or, Inquiries concerning the History of Law, Government, and Manners." Edinb. 1778, 4to. This work, of which there are several other editions, excited much attention on its first appearance. Hayley, who was then a popular writer, described the author as possessing "all the energy of genius."² His researches are conducted with judgment and sagacity; he grasps his subject with much vigour, and always expresses himself with boldness and force. In the progress of his discussions, he points out various mistakes of recent writers. One of these was Blackstone, who silently rectified the errors which he detected.³ The style of this work, though never languid or feeble, may however be considered as deficient in fluency and variety. His periods are too uniformly short, to be altogether pleasing to the ear. Long sentences he has elsewhere denounced in set terms. "This brevity," he avers, "is a conspicuous part of oratory, and is consistent with the greatest elevation and dignity. Where Cicero himself is most eloquent, and where the tide of his language is most rapid and powerful, his sentences are concise; and he avoids with care the periodic swell, as cold, artificial, and unnatural. And indeed it is to be laid down as a general rule, that where sentences are uniformly long, as in Milton and in Clarendon, there is no eloquence in the composition, and little connection in the argument."⁴

The chief value of the work consists in the vivid and striking picture which it exhibits of chivalry and the feudal system. In this respect it possesses some advantages over Dr Robertson's View of the Progress of Society in Europe, though it is not written with the same degree of classical elegance. "In the courtly and agreeable introduction to the History of Charles the Fifth," says Dr Stuart, "of which the scheme is so comprehensive, it is remarkable that, amidst a wide variety of other omissions, there is not even the slightest consideration of knight-service, and the knight's fee. Yet these circumstances were of a most powerful operation, both with respect to government and manners. I make not this remark to detract from the diligence of an author whose laboriousness is acknowledged, and whose total abstinence from all ideas and inventions of his own, permitted him to carry an undivided attention to other men's thoughts and speculations; but that, resting on these peculiarities, I may draw from them this general and humiliating, yet, I hope, not unuseful conclusion, that the study and knowledge of the dark ages are still in their infancy." This contemptuous mention of the great historian could scarcely fail to excite resentment, and of this resentment he speedily had occasion to prove the bitter effects.

The professorship of the law of nature and nations was at that period held by James Balfour; and in 1779, being then advanced in years, it was ascertained that he was willing to resign it for a valuable consideration. Here it is necessary to explain the very remarkable fact, that, under the sanction of the secretary of state, this professorship was

¹ See Dr Allen's American Biographical and Historical Dictionary, p. 449.

² English Review, vol. ii. p. 169.

³ Hayley's Essay on History, p. 157. Lond. 1780, 4to.

⁴ Edinburgh Magazine and Review, vol. v. p. 250.

Stuart. regularly bought and sold. The price of his resignation had already been fixed, and the chair, thus to be vacated, had been promised to Dr Stuart, when the negotiation was finally interrupted by a strong remonstrance from the principal; who might safely represent to the lord advocate that the habits of the candidate were not sufficiently academical, and that such an appointment would be highly unsatisfactory to himself, as well as to some of his colleagues. "While engaged in some of his studies and projected publications," we are informed, "he has been known to confine himself for many weeks to solitary literary labour, hardly ever stirring abroad for air and exercise; but he unfortunately indulged in occasional sallies of vastly too great latitude and even licentiousness."¹

This professorship was founded by the crown in the year 1707. The salary, payable out of the tithes of the bishopric of Edinburgh, amounted in 1802 to about L.350; but it was then reduced so low as L.80 or L.90, by an augmentation of stipend adjudged to the minister of St Cuthbert's. As an indemnity for this reduction, the professor obtained in 1806 a pension of L.200, payable during his incumbency. He had "purchased his commission," and he never read a single lecture. He survived till the year 1831, and no successor has been appointed. A middle way might certainly have been found between the conduct of one administration and that of another. The number of lucrative offices in this university is not superabundant, nor was it necessary to reduce their number by so minute a fragment of public economy. Even on the admission of the chair having been inefficient, this treatment, unless extended to some better-endowed universities, can scarcely be regarded as impartial. The professorship of the civil law at Oxford has long been as inefficient as the professorship of public law at Edinburgh. Why should the one be suppressed, and the other spared?

His qualifications for the office which thus seemed to be within his reach, were very eminent; and this signal disappointment of his hopes proved the greatest misfortune of his life. His resentment against Dr Robertson appears to have suggested all the works in which he afterwards engaged. This spirit is very easily to be discerned in his next publication, "Observations concerning the Public Law and the Constitutional History of Scotland: with occasional Remarks concerning English Antiquity." Edinb. 1779, 8vo. His extensive researches for the View of Society must evidently have abridged his labour of preparing these Observations, which contain much disquisition of a similar kind. The work is able and elaborate, nor can it be safely overlooked by any student anxious to investigate the constitutional history of our country. His antipathy to Robertson is unequivocally displayed in many passages; and, at the conclusion, he thus concentrates his sentiments of disparagement: "A propensity to embellish other men's notions, without considering enough on what authority they are founded, how strong they are in themselves, and what inferences are to be deduced from them, is a constant and a teeming source of mistake to this showy and elegant historian. It is thence that he holds out many a frail opinion to glitter and to perish. To collect these cannot be interesting to me. But, though I could not submit to make a chronicle of his errors, I have been induced to wipe away, and to dispel, in part, the stains and the gloom they would fix upon our story, and to illustrate, by examples, the respect which is due to his authority. And, while I perform this service to truth, to liberty, and to our national antiquities, I disdain to be unjust, and am far from being insensible to the peculiarities of his merit. It must be a pain, I know, to many of his readers, that the most widely amusing of all our writers, is

not at the same time the best informed, and the most able. They must regret that a work which forms so general, so easy, and so pleasing a pastime, is not also fraught with instruction, and loaded with wisdom; and that the author, who is deservedly so eminent in all the arts of courtly and popular composition, is not likewise remarkable for those superior qualities, which alone can secure and establish admiration, the power of thought, and the originality of sentiment." It is scarcely necessary for us to subjoin, that we are very far from being disposed to acquiesce in this general estimate.

This publication was speedily followed by "The History of the Establishment of the Reformation of Religion in Scotland." Lond. 1780, 4to. The work is written with his usual ability, but it cannot be affirmed that such an undertaking was peculiarly adapted to his habits of thinking. He however displays a greater degree of impartiality than could well have been anticipated. He is willing to admit that "a tribute of the highest panegyric and praise is justly to be paid to the actors in the Reformation. They gave way to the movements of a liberal and a resolute spirit. They taught the rulers of nations that the obedience of the subject is the child of justice, and that men must be governed by their opinions and their reason. Their magnanimity is illustrated by great and conspicuous exploits; which, at the same time that they awaken admiration, are an example to support and animate virtue in the hour of trial and peril. The existence of civil liberty was deeply connected with the doctrines for which they contended and fought. While they treated with scorn an abject and cruel superstition, and lifted and sublimed the dignity of man, by calling his attention to a simpler and wiser theology, they were strenuous to give a permanent security to the political constitution of their state."

Of this work, his next publication may be considered as the sequel: "The History of Scotland, from the Establishment of the Reformation till the Death of Queen Mary." Lond. 1782, 2 vols. 4to. Here the author has made a great, and indeed a splendid effort, to eclipse the reputation of Robertson, whom he both envied and hated. As the one historian considered Mary guilty of some of the foulest crimes laid to her charge, it was almost an obvious consequence that the other should represent her as innocent. Her innocence, he is willing to believe, has been demonstrated by Goodall and Tytler; but more recent writers, and especially Laing, have sufficiently disposed of their demonstrations; nor is it perhaps to be anticipated that any historian of eminence will hereafter desert the footsteps of Robertson to tread in those of Stuart. His work however displays great vigour of mind, and the style is more easy and flowing than that of his View of Society. Some of his characters are sketched with a powerful pencil. This history attracted no inconsiderable share of public attention on its first appearance, and, like his preceding volume, it reached a second edition, but it made little or no progress in supplanting the rival work; and the story of the ill-fated Mary's crimes and sufferings still continues to be chiefly read in the elegant and captivating pages of Robertson.

The preface to the History of Scotland is dated at London on the first of March 1782; and soon after this period, he undertook the management of the English Review, the property of the late John Murray, who had been the London publisher of his Magazine. Of "The English Review, or, an Abstract of English and Foreign Literature," the first number appeared at the commencement of the year 1783. One of his coadjutors was Whitaker, an uncandid and virulent critic, whose chief effort in this journal was a series of articles on Gibbon's History.² These he reprinted

¹ Kerr's Memoirs of Smellie, vol. i. p. 500.

² D'Israeli states that "he negotiated for Whitaker and himself a doctor of laws degree." (Calamities of Authors, vol. ii. p. 63.) This

Stud
||
Stuhlweissenburg.

in a separate form in the year 1791. In this English Review, some Scottish authors do not find much favour. The historical works of Dr Ferguson and Dr Watson receive a liberal portion of praise; but the Lectures of Dr Blair and the Dissertations of Dr Beattie are treated as works of very inferior merit and importance. It is observable that Smellie's translation of Buffon is not honoured with much commendation. Stuart had dedicated one of his works to the chief justice; but the subsequent passage, which occurs in an article apparently written by him, affords a sufficient indication of his altered sentiments: "Lord Mansfield, during the course of his long life, has been uniformly the zealous champion of prerogative; and has exerted and prostituted his abilities to undermine the trial by jury, and the liberty of the press, those sacred and formidable bulwarks which support the glorious fabric of the English government."

How long he continued to conduct the English Review, we are not informed. In 1785 he became the editor of "The Political Herald and Review; or a Survey of domestic and foreign Politics, and a critical Account of political and historical Publications." This work, it is believed, only reached a second volume. One of his coadjutors, in this as well as the English Review, was Dr Thomson, who, like himself, was too great a lover of Burton ale. Their favourite haunt was the Peacock in Gray's Inn Lane.¹ It is too well known that Stuart's mode of life had been such as to impair his health and strength. With a constitution undermined by disease, and a mind soured by disappointment, he embarked for Leith, and sought a place of rest under the roof of his father, who having become emeritus professor in 1775, was then residing at Musselburgh. The son was labouring under a dropsy, from which the usual operation afforded him a temporary relief; but all medical aid was ineffectual, and he descended to his grave at the premature age of forty-four. He died on the 13th of August 1786, and his father survived till the 18th of June 1793.

Gilbert Stuart is thus described by a writer who seems to have had some personal knowledge of him: He "was about the middle size, and justly proportioned. His countenance was modest and expressive, sometimes announcing sentiments of glowing friendship, of which he is said to have been truly susceptible; at others, displaying strong indignation against folly and vice, which he had also shewn in his writings. With all his ardour for study, he yielded to the love of intemperance, to which, notwithstanding a strong constitution, he fell an early sacrifice."² (x.)

STUD, in the manège, a collection of breeding horses and mares.

STUDY (Ital. *Studio*), a piece of instrumental music composed for the purpose of familiarizing the player with some of the difficulties of his instrument. Thus we have studies for the violin by Fiorillo, Kreuzer, Rode, Spohr, Paganini; and for the pianoforte by Clementi, Cramer, Kalkbrenner, and others.

STUDDING-SAILS, certain light sails, extended, in moderate and steady breezes, beyond the skirts of the principal sails, where they appear as wings upon the yard-arms.

STUFF, in commerce, a general name for all kinds of fabrics of gold, silver, silk, wool, hair, cotton, or thread, manufactured on the loom; of which number are velvets, brocades, mohairs, satins, taffetas, cloths, serges, &c.

STUHLWEISSENBURG, a city of the kingdom of Hungary, in the province of the Farther Danube, the capital of a circle of the same name. It stands in a marshy situation on the river Sarvitz, is the seat of a Catholic bishop,

and of several inferior courts of judicature. Besides a cathedral, it has several Catholic churches, and one for the United Greeks, and likewise two monasteries. It contains 1330 houses, with 12,380 inhabitants, who are chiefly dependent on agriculture, especially on vineyards, but are also employed in manufacturing flannel and other woollen goods. Long. 18. 19. 25. E. Lat. 47. 11. 34. N.

STUKELEY, WILLIAM, an eminent antiquary, descended from an ancient family in Lincolnshire, was born at Holbech in that county, on the 7th of November 1687. From the free school of his native town he was removed to Corpus Christi College, Cambridge, where he was admitted on the 7th of November 1703. Having chosen the medical profession, he took the degree of M. B. in 1709, and that of M. D. in 1719. He first settled as a practitioner at Boston; but in 1717 he removed to London, and was admitted a fellow of the College of Physicians in 1720. By the recommendation of Dr Mead, he was chosen a fellow of the Royal Society. He contributed to the re-establishment of the Society of Antiquaries; of which he officiated as secretary for many years. In 1726 he left the metropolis, and settled at Grantham in Lincolnshire, where he soon obtained extensive practice. In 1728 he married Frances, the daughter of Robert Williamson, Esq. of Allington, a lady of good family and fortune. Being much afflicted with the gout, he found the exercise of his profession very laborious, and therefore meditated a retreat into the church. On the 20th of July 1720, being then in the thirty-third year of his age, he received ordination from Archbishop Wake; and in the ensuing October was presented by the lord-chancellor King to the living of All-Saints in Stamford. He became a widower in 1737, and, in the course of the following year, married the only daughter of Dr Gale, the learned dean of York. In 1739 the living of Somerby near Grantham was bestowed upon him by the duke of Ancaster. In 1747 the duke of Montagu presented him to the rectory of St George, Queen Square, and he then vacated his other benefices. He survived till the 3d of March 1765. On the 27th of the preceding month, he had been struck with palsy, after attending a full vestry on a contested election for a lecturer. The apartment was much heated; and on returning through his garden, accompanied by Serjeant Eyre, "they both caught their deaths, for the serjeant never was abroad again, and the doctor's illness came on that night." By his first wife Dr Stukeley had three daughters, one of whom died young, and the other two survived him. The one was married to Mr Richard Fleming, an eminent solicitor, and the other to the Rev. Thomas Fairchild, rector of Pitsey in Essex. They both died in 1782. Of his second marriage there was no issue.

Dr Stukeley was a man of varied learning, but was chiefly distinguished by his knowledge of antiquities. His writings are numerous, and partly relate to medical, as well as theological subjects; but we shall confine ourselves to an enumeration of the most important or curious of his antiquarian publications. An Account of a Roman Temple near Graham's Dike. 1720, 4to. Of the Roman Amphitheater at Dorchester. Lond. 1723, 4to. *Itinerarium Curiosum*; or, an Account of the Antiquities and remarkable Curiosities in Great Britain. Lond. 1724, fol. Lond. 1776, 2 vols. fol. Stonehenge; a Temple restor'd to the British Druids. Lond. 1740, fol. Abury; a Temple of the British Druids: with some others described. Lond. 1743, fol. *Palæographia Britannica*; or, Discourses on Antiquities in Britain. Lond. 1743-52, 4to. An Account of Richard of

Stukeley.

supposed negotiation he apparently refers to the year 1783, or some period subsequent to the appearance of the English Review. The degree had very honourably been conferred upon Stuart many years before; and John Whitaker, on whom it was never conferred, was a B. D. of Oxford.

¹ Annual Obituary, vol. ii. p. 101.

² General Biographical Dictionary, vol. xxviii. p. 474.

Stupor Cirencester. Lond. 1757, 4to. The Medallic History of Marcus Aurelius Valerius Carausius, Emperor in Britain. Stuttgart. Lond. 1757-9, 2 vols. 4to.

STUPOR, a numbness in any part of the body, whether occasioned by ligatures obstructing the blood's motion, by the palsy, or the like.

STURM, JOHN, better known by the name of Sturmius, a learned philologist and rhetorician, was born at Schleiden in Eissel, near Cologne, on the 1st of October 1507. He studied at first in his native country with the sons of Count von Manderscheid, whose receiver his father was. He afterwards pursued his study at Liege, in the college of St Jerome, and then went to Louvain in 1524. He there spent five years, three in learning and two in teaching. He set up a printing-press with Rudger Rescius, professor of the Greek tongue, and printed several Greek authors. In 1529 he went to Paris, where he was highly esteemed, and read public lectures on the Greek and Latin writers, and on logic. There he married, and kept a great number of boarders: but as he was inclined to what were called the new opinions, he was more than once in danger; and this undoubtedly was the reason why he removed to Strasburg in 1537, in order to take possession of the place offered him by the magistrates. The year following he opened a school, which became famous, and by his means obtained of Maximilian II. the privileges of a university in the year 1566. He was very well skilled in polite literature, wrote Latin with great purity, and was an able teacher. His talents were not confined to the school; for he was frequently intrusted with deputations in Germany and foreign countries, and discharged these employments with great honour and diligence. He showed extreme charity to the refugees on account of religion: he not only laboured to assist them by his advice and recommendations, but he even impoverished himself for them. He died on the 3d of March 1589, in the eighty-second year of his age, after he had been for some time blind. Although he was thrice married, he left no children. He was a learned writer, and published various works, which were found to be useful and important by his contemporaries. One of these was an edition of Cicero in nine vols. 8vo. He bestowed much labour in elucidating the rhetorical works of Aristotle, Hermogenes, and Cicero. With the view of improving the system of education, he published several treatises; one of which was frequently reprinted. It is entitled "De Literarum Ludis recte aperiendis liber." Argent. 1538, 4to. F. A. Hallbauer edited a collection of his tracts, under the title "De Institutione Scholastica Opuscula omnia." Jenæ, 1730, 8vo. The name of Sturmius is familiar to the reader of Ascham's epistles. He must not be confounded with John Sturm, a native of Mechlin, and physician and professor of mathematics at Louvain, who also wrote several works.

STURMINSTER-MARSHAL, a town of the hundred of Cogdean and county of Dorset, 104 miles from London. It has a large church, and had formerly a market, which has of late years been disused. It stands on the river Stour. The number of inhabitants amounted in 1801 to 604, in 1811 to 662, in 1821 to 715, and in 1831 to 803.

STURMINSTER-NEWTON, a town in the hundred of the same name in the county of Dorset, 111 miles from London. It stands on the river Stour, and had once a considerable trade in making flannels, baize, and blankets; but of late it has declined. The buildings are indifferent, but it has a fine church, lately repaired. The market is held on Thursday. The inhabitants amounted in 1801 to 1406, in 1811 to 1461, in 1821 to 1612, and in 1831 to 1831.

STUTTGART, the capital of the kingdom of Wirtemberg, stands in a beautiful valley, and is surrounded on every side with hills of very moderate elevation, which are clothed to the tops with vineyards. The valley is watered by a clear and rapid but not copious river, which meanders

VOL. XX.

through the walks at the extremity of the city. A great part of the city is composed of fine and modern buildings, and those streets are clean, well paved, and light. The royal palace is an extensive and magnificent pile of building; and the theatre, opera-house, the gymnasium, and the Catholic church, are fine specimens of architecture. Though there are no fortifications, the entrance to the city is through handsome gates, and one of them of most imposing beauty. Besides the gymnasium, there are other institutions for instruction; and the collection of ancient paintings, and the workshop of the sculptor Daneker, will be a treat to an amateur of the fine arts. The inhabitants amounted in 1817 to 26,016, and in 1831 had increased to 31,500. It is a place of little trade beyond what arises from supplying the court and the nobility that resort to it. Long. 9. 5. 33. E. Lat. 46. 48. 32. N.

STYLE, a word of various significations, originally deduced from *stylos*, a kind of bodkin wherewith the ancients wrote on plates of lead, or on wax, &c. and which is still used to write on ivory leaves and paper prepared for that purpose.

STYLE, in language, is the peculiar manner in which a man expresses his conceptions. It is a picture of the ideas which rise in his mind, and of the order in which they are there produced. See RHETORIC.

Old STYLE, the Julian method of computing time, as the **New STYLE** is the Gregorian method of computation. See CHRONOLOGY.

STYLITES, PILLAR SAINTS, in *Ecclesiastical History*, an appellation given to a kind of solitaries, who stood motionless upon the tops of pillars raised for this exercise of their patience, and remained there for several years, amidst the admiration and applause of the stupid populace. Of these we find several mentioned in ancient writers, and even as low as the twelfth century, when they were totally suppressed. The founder of the order was Simeon Stylites, a famous anchorite in the fifth century, who first took up his abode on a column six cubits high, then on a second of twelve cubits, a third of twenty-two, a fourth of thirty-six, and on another of forty cubits, where he thus passed thirty-seven years of his life. The tops of these columns were only three feet in diameter, and were defended by a rail that reached almost to the girdle, but did not permit the votary to lie down. The faquirs, or devout people of the east, imitate this insane mode of life to the present day.

STYX, in *Fabulous History*, a river of hell, round which it flows nine times. The gods held the waters of the Styx in such veneration, that to swear by them was reckoned an oath altogether inviolable. If any of the gods had perjured themselves, Jupiter obliged them to drink the waters of the Styx, which lulled them for one whole year into a senseless stupidity; for the nine following years they were deprived of the ambrosia and the nectar of the gods; and after the expiration of the years of their punishment, they were restored to the assembly of the deities, and to all their original privileges. It is said that this veneration was shown to the Styx, because it received its name from the nymph Styx, who with her three daughters assisted Jupiter in his war against the Titans.

Styx was a river which it was necessary for departed shades to pass before they could enter the infernal regions; and it was the office of Charon to ferry them over. Mythological writers have said that the Egyptians framed both this and some other fables relating to the dead, from certain customs peculiar to their country; that in particular there was, not far from Memphis, a famous burying-place, to which the dead bodies were conveyed in a boat across the lake Acherusia; and that Charon was a boatman who had long officiated in that service. The learned Dr Blackwell, in his *Life of Homer*, has observed, that, in the old Egyptian language, *Charoni* signified "ferryman."

Style
||
Styx.

Suakin
||
Suarez.

SUAKIN, a seaport town of Nubia, situated on the western coast of the Red Sea, was formerly a place of great wealth and importance, but has long been in a declining state, and is now almost in ruins. Suakin looks better when seen at a distance than on a nearer view; the buildings all white-washed and on an elevated site, and two minarets, giving the town a handsome appearance. Like all the towns in the east, it has narrow and dirty streets. All that remains of its former grandeur is its capacious port, which is capable of containing 200 large vessels, that can anchor close to the island in seven fathoms water; but is so narrow at the mouth as to render an entrance impracticable, except with the most favourable wind. It is rather remarkable that this narrow passage should have so long remained open, considering the clouds of sand which are borne toward it at one season, and the action of the sea continually breaking over it, after having passed over sandbanks. The Turks obtained possession of Suakin at the same time that they occupied the opposite coast of Arabia. In the fifteenth century Suakin was a place of great importance and wealth, the emporium of the Red Sea, and one of the richest cities in the east. It derived its importance from its being in the middle ages the maritime capital of the Turks in the Red Sea, when that empire maintained there a powerful navy. Suakin has declined along with the Turkish power; and its only support is now derived from its being the channel of communication between Arabia and the interior of Africa. Pilgrims and slave-dealers, or persons who combine these two vocations, quit the Nile at Shendi, and proceed through Taka and other districts of Nubia to this port, where they embark for Jidda. They carry with them slaves, with a little ivory and gold, and take Indian goods in return. The surrounding country is arid and barren, and produces no grain except that coarse species called dhourra or juwarry. There is abundance of good water, which is preserved in wells and tanks. Fish are cheap and plentiful, and the mullets are particularly fine. Sheep are cheap, and do not cost above a dollar each. But fowls are scarce and dear. The country around, and the coast to a considerable extent, is occupied by a hardy race of Bedouin Arabs, called Suakini. Suakin is supposed to be the Soter Limen of Diodorus, the Theon Scter of Ptolemy; though it is not easy to conceive how these terms, signifying "the safe harbour," could apply to one of such difficult entrance. Long. 37. 33. E. Lat. 19. 48. N.

SUAN, a small town of Hindustan, in the province of Bahar, district of Rotas. It is twenty-five miles south-east from Patna. Long. 86. 25. E. Lat. 25. 16. N.

SUAREZ, FRANCIS, a renowned Jesuit, was born at Grenada on the 5th of January 1548. He belonged to a noble family, and was sent to prosecute the study of law in the university of Salamanca; but when he had finished his course, he was induced to change his destination, and assume the habit of St Ignatius. He at first experienced much difficulty in comprehending the principles of the philosophy which was then taught; but having been placed under the guidance of Rodriguez, he soon began to be distinguished by the uncommon rapidity of his progress, and became one of the most distinguished members of the society. Having taught philosophy at Segovia, he was afterwards employed in teaching theology at Valladolid, Rome, Alcala, and Salamanca. Wherever he taught, his lectures attracted a numerous auditory. He was at length appointed to the first chair of divinity in the university of Coimbra; but before entering upon his office, he went to Evora, and took his doctor's degree. Here his reputation continued to increase. At the instigation of the pope, he prepared an elaborate work, entitled "*Defensio Catholicæ Fidei contra Anglicanæ Sectæ Errores*." Conimbricæ, 1613, fol. This work gave much offence to King James, and was burnt at St Paul's by the hands of the hangman. Nor did it receive

better treatment from the parliament of Paris; who, by an *arrêt* pronounced on the 26th of June 1614, condemned it to the flames, as containing maxims contrary to the rights of sovereigns. It was ably refuted by Robert Abbot, afterwards bishop of Salisbury. Suarez, having been called to Lisbon for some weighty conference, died there on the 25th of September 1617. An instant before he expired, he said to those who surrounded his bed, "I never knew it was so pleasant to die."

Suarez was a great master of the scholastic philosophy and theology of his age, nor was he a mean or ordinary proficient in jurisprudence. Grotius has described him as the most acute of philosophers and divines. His treatise "*De Legibus et Deo Legislatore*," is commended by Sir James Mackintosh, "as exhibiting the most accessible and perspicuous abridgment of the theological philosophy in its latest form." According to the same competent authority, "he first saw that international law was composed, not only of the simple principles of justice applied to the intercourse between states, but of those usages, long observed in that intercourse by the European race, which have since been more exactly distinguished as the consuetudinary law acknowledged by the Christian nations of Europe and America." Of this learned Jesuit, the works are very numerous. An edition of them in twenty-three vols. fol. began to be published at Maintz and Lyon in the year 1630. An edition was published at Venice in the year 1740. (x.)

SUBAH, the general name of the viceroyships, or greater governments, into which the Mogul empire was divided, consisting of several provinces: the jurisdiction of a subahdar, the same as subahship, subaedar, or nizamat.

SUBAH DAR, the viceroy, lord-lieutenant, or governor, holding a subah; the same as nabob or nazim. Also the black commander of a company of sepoys.

SUBALTERN, a subordinate officer, or one who discharges his post under the command and subject to the direction of another; such are lieutenants, sub-lieutenants, cornets, and ensigns, who serve under the captain.

SUBARKAN, a village of Diarbekir, in Asiatic Turkey, on the Euphrates, seventy-five miles east-south-east of Kerkesieh.

SUBBULGUR, a town of Hindustan, in the province of Agra. It is surrounded by a high stone wall in good repair, with a number of bastions; but has few cannon mounted. On one side of the fort is a deep precipice. The country in the vicinity is well cultivated. It is sixty-five miles south-west from the city of Agra. Long. 75. 25. E. Lat. 26. 22. N. There is another town of the same name in the province of Delhi, situated on the east side of the Ganges. The town is surrounded by a very extensive line of fortification, though it exhibits, as well as the walls, little more than falling ruins. The town is improving since it came under British authority. It is twelve miles south from Hurdwar. Long. 78. 10. E. Lat. 29. 48. N.

SUBDEACON, an inferior minister, who anciently attended at the altar, prepared the sacred vessels, delivered them to the deacons in time of divine service, attended the doors of the church during communion-service, and went on the bishop's embassies with his letters or messages to foreign churches. They were so subordinate to the superior rulers of the church, that, by a canon of the council of Laodicea, they were forbidden to sit in the presence of a deacon without his leave. According to the canon law, a person must be twenty-two years of age to be promoted to the order of sub-deacon.

SUBDOMINANT, in *Music*. See *MUSIC*.

SUBDUPLICATE RATIO is when any number or quantity is contained in another twice. Thus 3 is said to be subduple of 6, as 6 is duple of 3.

SUBDUPLICATE RATIO of any two quantities, is the ratio of their square roots.

Subaa
||
Subdupli-
cate Ratio.

Subito
||
Succadana.

SUBJECT, in *Music*. See MUSIC.

SUBITO, in the Italian music, is used to signify that a thing is to be performed quickly and hastily; thus we meet with *volti subito*, turn over the leaf quickly.

SUBLIMATE, a chemical preparation, consisting of quicksilver united with muriatic acid.

SUBLIMATION, in *Chemistry*, the condensing and collecting, in a solid form, by means of vessels aptly constructed, the fumes of bodies raised from them by the application of a proper heat.

SUBMULTIPLE, in *Geometry*, &c. A submultiple number or quantity is that which is contained a certain number of times in another, and which, therefore, repeated a certain number of times, becomes exactly equal thereto. Thus 3 is a submultiple of 21. In this sense a submultiple coincides with an aliquot part.

SUBMULTIPLE RATIO, is that between the quantity contained and the quantity containing. Thus the ratio of 3 to 21 is submultiple. In both cases submultiple is the reverse of multiple: 21, *e. gr.* being a multiple of 3, and the ratio of 21 to 3 a multiple ratio.

SUBPŒNA, in *Law*, a writ by which persons are called into chancery, in cases where the common law has provided an ordinary remedy; and the name of it proceeds from the words therein, which charge the party called to appear at the day and place affirmed, "*sub pœna centum librarum*," &c.

SUBREPTITIOUS, or SURREPTITIOUS, a term applied to a letter, license, patent, or other act, fraudulently obtained of a superior, by concealing some truth which, had it been known, would have prevented the concession or grant.

SUBROGATION, or SURROGATION, in the civil law, the act of substituting a person in the place, and entitling him to the rights, of another. In its general sense, subrogation implies a succession of any kind, whether of a person to a person, or of a person to a thing.

SUBROY, a small town of Hindustan, province of Cutch, on the Gulf of Cutch, from which place it is distant twenty-three miles to the north. This town stands on a rising ground on the road from Luckput Bunder to Mundavie, and is defended by a castle. It is populous and flourishing, and the surrounding country is tolerably well cultivated.

SUBTRACTION, or SUBTRACTION, in *Arithmetic*, the second rule, or rather operation, in arithmetic, whereby we deduct a less number from a greater, to learn their precise difference.

SUBTANGENT OF A CURVE, the line that determines the intersection of a tangent with the axis, or that determines the point wherein the tangent cuts the axis prolonged.

SUBTENSE, formed from *sub*, under, and *tendo*, I stretch, in *Geometry*, a right line which is opposite to an angle, and drawn between the two extremities of the arc which measures that angle.

SUBUNREEKA, a river of Hindustan, which has its source in the province of Bahar, district of Chuta Nagpoor, whence it flows in a south-easterly direction, and after a winding course of 250 miles falls into the Bay of Bengal. It is fordable except in the rainy season. It was the first river of Bengal into which Europeans were allowed to enter. The channel is now choked up with sand.

SUCCADANA, a town on the west coast of the island of Borneo. It is situated on the principal or southern outlet of a large river, which is navigable 150 miles for prows. It is celebrated for very large diamonds, and also for the best camphire; and is a considerable mart for opium, the sale of which is monopolized by the rajah and his family. It is the custom here, as at all the eastern ports, to give a present at the first audience, in proportion to the rank of the person visited; to the king about fifty dollars, to the rajah thirty, and the shahbunder and agent about twenty

each. Gold dust, tin, and pepper, are also to be procured here. Lat. 1. 30. S.

SUCCULA, in *Mechanics*, an axis or cylinder with staves in it to move it round, but without any tympanum or peritrochium.

SUCKLING, SIR JOHN, an English poet and dramatist, was the son of Sir John Suckling, comptroller of the household to King Charles I. and was born in the year 1608-9. He is supposed to have been born at Twickenham, as it appears from the parish-register that he was baptized there on the 10th of February. He discovered an uncommon aptitude for the acquiring of languages, insomuch that he is reported to have spoken Latin at five years of age, and to have written it at nine. When he grew up, he travelled; but seems to have affected nothing more than the character of a courtier and fine gentleman; which he so far attained that he was allowed to have the peculiar happiness of making every thing he did become him. In his travels he made a campaign under the great Gustavus Adolphus; and his loyalty, if not his valour, appeared in the beginning of our civil wars; for, after his return to England, he raised a troop of horse for the king's service, entirely at his own charge, and mounted them so completely and richly that they are said to have cost him L.12,000. This troop, with Sir John at its head, behaved so ill in the engagement with the Scots, upon the English borders, in 1639, as to occasion a famous lampoon, composed by Sir John Mennis, which was set to a brisk tune, and much sung by the parliamentarians. This disastrous expedition, and the ridicule that attended it, were supposed to have hastened his death; but he survived till the 7th of May 1741. He was a sprightly wit and an easy versifier, but no great poet. His poems, plays, speeches, tracts, and letters, were collected into an octavo volume in the year 1709.

SUCKUT, a small town and district of Hindustan, province of Lahore, intersected by the Beyah river, belonging to the Sikhs. Long. 75. 45. E. Lat. 32. 41. N.

SUCTASGUR, a town and fortress of Hindustan, province of Allahabad. The fortifications were formerly more considerable, and defended the passes of the western hills. They are now neglected. It is the capital of a small district, which was included in the collectorship of Benares. It is fourteen miles south of the fortress of Chunar.

SUDASHYGUR, a fortress of Hindustan, on the western shore of the province of Canara. It is situated on a high point of land, and being remarkably white, is a conspicuous point from the sea. It commands the entrance of the Aliga river.

SUDATORY, a name given by the ancient Romans to their hot or sweating-rooms; sometimes also called *Laconica*.

SUDBURY, a town in the hundred of Babergh and county of Suffolk, fifty-six miles from London. It stands on the river Stour, which divides it from Essex, and is navigable to the sea by Manningtree. The town comprises three parishes, with each a church, and is tolerably well built. It was one of the earliest seats of the woollen manufacture, some share of which it still retains; and it has likewise some silk trade. It is a borough, governed by a mayor, six aldermen, and twenty-three common-council men, and returns two members to the House of Commons. It has a good market on Saturdays. The inhabitants in 1801 amounted to 3283, in 1811 to 3471, in 1821 to 3950, and in 1831 to 4677.

SUECA, a city of Spain, in the province of Valencia, and government of Alcira. It stands on the banks of the river Xucar, in a marshy soil, which, though not very favourable to health, is well adapted for the growth of rice, which is here cultivated to a great extent. In the town there is a church, with a monastery and a chapel; and it contains 700 dwellings, with 4800 inhabitants.

Succula
||
Sueca.

Suen-Hoa
||
Suez.

SUEN-HOA, a city of China, of the first rank, in the province of Pe-che-lee, situated among the mountains near the great wall. It is a populous place, well built, and distinguished by the beauty of its streets. The district includes a considerable number of forts destined to defend the great northern barrier of the empire. It is seventeen miles north-west of Pekin.

SUETONIUS TRANQUILLUS, CAIUS, a Latin historian, was the son of Suetonius Lenis, who became a military tribune in the reign of the emperor Otho. The son is supposed to have been born about the beginning of the reign of Vespasian. Having betaken himself to the practice of the law, he appears to have acquired reputation as a pleader. He lived on terms of intimacy with the younger Pliny, who recommended him to Trajan as a very learned and upright man, and obtained for him the "jus trium liberorum." Although he had a wife, he was without children; and a participation of this privilege was of some importance to him in the exercise of his profession. After the death of this emperor, he was appointed secretary to Hadrian; but he was dismissed from his office in consequence of his having manifested a want of due respect for the empress Sabina. After his retirement from public life, he had more leisure to devote himself to literary pursuits. Of that period of Roman history, his principal work, "Vitæ duodecim Cæsarum," contains the most curious and characteristic record which has been transmitted to our times. The picture which he exhibits is certainly a very foul one, but on that account is more likely to be true. His lives are not digested according to any order strictly chronological, but it is rather his plan to combine curious, interesting, and characteristic particulars, which serve to mark the progress of the different emperors, most of whom were a disgrace to human nature. Other two works of a slighter texture, "De illustribus Grammaticis liber," and "De claris Rhetoribus liber," bear the name of Suetonius. To him are likewise ascribed very brief lives of Terence, Horace, Lucan, Persius, Juvenal, and the elder Pliny.

Suetonius was twice printed at Rome during the same year, 1470, and several other editions appeared at an early period. We pass over these, and hasten to mention the valuable editions of Casaubon, printed at Geneva in quarto in the years 1595 and 1615. His commentary abounds with recondite learning. Another elaborate edition was published by Grævius, Hag. Com. 1672, 4to. It was reprinted at the same place in 1691, and at Utrecht in 1703. This learned editor was soon succeeded by Pitiscus, Traj. ad Ren. 1690, 2 tom. 8vo. Leovard. 1714, 2 tom. 4to. But an edition still more elaborate was produced by the indefatigable Burman, Amst. 1736, 2 tom. 4to. And after no long interval, he was followed by Oudendorp, Lugd. Bat. 1751, 2 tom. 8vo.

SUEVI, a common name of the people situated between the Elbe and the Vistula, distinguished otherwise by particular names.

SUEVUS, in *Ancient Geography*, a river of Germany, thought to be the same with the Viadrus or Oder, emptying itself at three mouths into the Baltic, the middlemost of which is called *Swine* or *Swene*, which last comes near the name *Suevus*.

SUEZ, a seaport situated at the northern extremity of the gulf of the same name. It is so incommodious that small boats can with difficulty land at the quay even at high water. The town is in a ruinous state, walled on the west and south-west; but the wall is rapidly falling to decay. The population only consists of about a dozen agents, who receive goods from the ports of the Red Sea, and forward them to their correspondents at Cairo, together with some shopkeepers, who deal chiefly in provisions. Neither merchants nor artisans live in it. The pacha keeps a garrison here of about fifty horsemen, with an officer, who commands the town,

the neighbouring Arabs, and the shipping in the harbour. Suez is one of the few harbours in the Red Sea where ships can be repaired. Although the port is now little frequented, the trade in coffee and India goods still passes this way to Cairo.

The isthmus of Suez is a low-lying land, composed of shell limestone rock, mixed with strata of siliceous limestone, and partly covered with sands or with saline marshes. In several places the solid strata are with difficulty perceived by their slight undulations; in the northern part in particular there is a vast plain, varied only by sand-hills. To the east, the south-east, and the south-west, the mountain-chains of Arabia Petræa and of Egypt skirt at a distance the table-land of the isthmus, which is terminated at the Red Sea. The lake Birket-el-Ballah adjoining Lake Menzaleh, Temsah or Crocodile Lake, and the almost dry basin of the Bitter Lakes, form from north to south a series of depressions, interrupted only by stripes of low land. The breadth of the isthmus, in a straight line from the mouth of Tineh on the Mediterranean to the northern point of the Gulf of Suez, is 378,844 feet, or nearly seventy-two miles.

The question whether or not the Isthmus of Suez has always existed, has given rise to much discussion among the learned; some maintaining that this neck of land was formerly covered by the sea, and that Africa was an island; others that it must formerly have been much narrower than it is now; and others that it has undergone little or no change. This latter hypothesis is defended by D'Anville, in opposition to the opinions of Gossellin and Rosière, whose arguments are in favour of the contraction of the gulf.

The surface of the isthmus generally declines from the shores of the Red Sea towards those of the Mediterranean; and the level of the latter is thirty feet lower than that of the Gulf of Suez. There is a similar descent towards the Delta and the bed of the river Nile; the level of the water of the Nile at Cairo, when at its lowest, being about nine feet lower than the surface of the gulf at low water. But the Nile rising sixteen cubits by the Nilometer, is nine feet higher than the Red Sea at high water, and fourteen higher than the same sea at low water. Besides these leading inclinations of the surface, there is a particular one in the middle of the isthmus. The deep basin called the Bitter Lakes is more than fifty-four feet lower than the level of the Red Sea, the waters of which would enter and fill it if they were not prevented by a little sandy isthmus about three feet above the level of the sea.

From this it follows that the Red Sea never could have occupied the basin of the Bitter Lakes in a constant manner, because its waters, if raised sufficiently high to form such a communication, would have found no barrier to the north of that basin: they would have flowed all the way to the Nile by the Ras-el-Ooadi, and to the Mediterranean by the Ras-el-Mayah. The two seas thus brought into contact would have reached a common level, and the strait would have become permanent.

But if a natural communication between the two seas has never existed within the periods of human record, the traces and remains of a canal have been ascertained with satisfactory precision. From Balbeis, on the old Pelusiæ branch of the Nile, now the Canal of Menedji, this canal reaches to Ablaseh, the ancient Thou. There it enters the narrow valley of Arabes-Tommylat, the level of which is thirty-three feet lower than that of the Red Sea. It passes on to Abookesheyd, which is supposed to be the old Heroopolis. The basin of the Bitter Lakes might have been filled at pleasure from the waters of the Nile.

Beyond this basin the traces of the canal re-appear in the isthmus which separates the lakes from the Red Sea, and show that the canal was continued the whole way. According to Strabo, this canal was constructed by the Ptolemies; and the Arabian writers assert that it was opened

Suez.

Suffolk. again by order of the Caliph Omar, and was used for navigation from the year 644 to 767; at which time another caliph caused it to be shut up, in order to deprive a rebel chief of his supplies of provisions. While the French army was in Egypt, some learned discussions were maintained on the practicability and advantages of its restitution. But however useful its re-establishment might be to the country through which it passes, it is very problematical if it could ever be rendered a medium of commercial communication on a large scale.

SUFFOLK, an English maritime county, on the borders of the German Ocean. It is bounded on the east by the sea; on the south by Essex, from which it is divided by the river Stour; on the west by Cambridgeshire; and on the north by Norfolk. Its medium length from east to west is forty-seven miles, and its breadth from north to south twenty-seven. The square contents are 1512 miles, or 967,680 statute acres. It consists of two grand divisions, one called the Liberty of Bury, the other the Guildable Land, each of which furnishes a distinct grand jury at the assizes. The next division is into twenty-one hundreds, and these are subdivided into five hundred and twenty-three parishes. The entire country forms a part of the diocese of Norwich.

Population. The population of this county at the four decennial periods of enumeration was found to amount in 1801 to 210,431, in 1811 to 234,211, in 1821 to 270,542, and in 1831 to 296,000.

At the last period the occupiers of land employing labourers were 4,526
 Occupiers not employing labourers..... 1,121
 Labourers employed in agriculture.....33,040
 Labourers employed in manufactures..... 676
 Labourers employed in retail trade or handicraft...18,167
 Capitalists, bankers, &c..... 2,228
 Labourers not agricultural..... 5,336
 Other labourers under twenty years of age..... 4,940
 Males at and above twenty years.....71,376
 Male servants..... 2,032
 Female servants.....11,483

In the same year the number of families chiefly employed in agriculture was found to be 31,491; those chiefly employed in trade, manufactures, and handicraft, were 18,116; and those comprised in neither of the preceding classes were 11,926. The number of inhabited houses was 50,139, occupied by 61,533 families; the uninhabited houses were 1141, and those building 259.

The annual value of the real property of the county, as assessed for the purposes of the property-tax in the year 1813, was L.1,127,404.

TOWNS. The towns of this county containing more than 2000 inhabitants, with their population in 1831, were the following:
 Ipswich20,454
 Bury St Edmund's.....11,436
 Woodbridge 4,769
 Sudbury..... 4,677
 Lowestoffe..... 4,238
 Beccles 3,862
 Bungay..... 3,734
 Hadleigh 3,425
 Mildenhall..... 3,267
 Long Melford..... 2,514
 Halesworth..... 2,473
 Framlingham..... 2,445
 Eye..... 2,313
 Newmarket, but a part of this town, with 714, is in Cambridgeshire..... 2,134
 Gorleston, a suburb to Yarmouth in Norfolk, and by the reform bill a part of that borough..... 2,111
 Lavenham..... 2,107
 Brandon..... 2,065

Suffolk is generally a level tract of country, in which, as

there are few elevations, there are scarcely any extensive prospects. It is, however, tolerably well clothed with trees, but wants running water; most of the streams being very sluggish in their course, and by no means copious. The soil is as various as in other districts of the same extent. On the sea-coast it is in general sandy, but rendered productive by the application of shell-marl, which is found in abundance. In the middle of the county, from north to south, called usually High Suffolk, which is the larger part, the soil is a tenacious, loamy clay, affording good pasturage for cows, whose butter is chiefly used to supply the London markets.

The north-western division is a poor sandy soil, in many places covered with heath, and scarcely fit for any other purpose than that of feeding sheep or breeding rabbits, of which latter animals, it is said, the skins of more than 40,000 annually supply fur to the hatters. The corn furnished by the eastern division of the county, besides supplying its vicinity, is sent to London from the ports of Ipswich and Woodbridge. The cultivation is commonly conducted on the Norfolk system of turnips, barley, clover, and wheat; and the husbandry being well executed, the crops are generally very good. The beans are peculiarly productive. Turnips, and in some districts carrots, are extensively cultivated. Hemp is grown in the garden of almost every peasant, and spun into linen for their domestic uses. Some few hops are grown in the vicinity of Stowmarket.

They have an excellent breed of draught-horses, well known by the name of Suffolk punches. The cows have been long celebrated for the abundance of their milk, which, in proportion to their size and the quantity of food they consume, exceeds the produce of any other race in the kingdom. They are all without horns. The sheep, of which large flocks are kept, are mostly of the Norfolk breed; but of late years they have been changed for those of the South Downs.

There are few manufactures in this county, though it was the first in which the Flemings introduced the cloth-making trade. Before the extension of machinery in the northern counties, the females found constant winter employment in spinning worsted, but that has ceased. A small portion of the manufacture of mixed silk and worsted stuffs is retained, in which 269 males above twenty years of age are employed at Sudbury, forty-two are so employed at Glemsford, and a few at Lavenham and at Hadleigh. At Brandon no less than sixty men are employed in making gun-flints. There is some coarse linen made from hemp at Haverhill, and a little bone-lace at Eye.

The branch of industry which, next to agriculture, gives employment to the greatest number of inhabitants, is the fishery. Many vessels are equipped at Lowestoffe and Southwold to take herrings, which are cured in houses appropriated for that purpose in these towns. The taking of mackerel is beneficial before the season when the shoals of herrings arrive on the coast. There is little other commerce in the county than that which arises from the transmission of the agricultural products to the metropolis.

The navigable rivers are the Sark, which passes by Thetford, and runs to the Ouse; the Deben, which runs by Woodbridge to the sea; the Orwell, a beautiful river, navigable to Ipswich; and the Blythe, navigable to Framlingham. To these may be added the Wavenay, which forms the northern boundary of the county; and the Stour, which is its southern. The only navigable canal is one between Ipswich and Stowmarket; but the river Yare having been rendered navigable to Norwich, has a canal at its mouth at Lowestoffe in this county: the admission is by gates, which exhibit one of the most complete specimens of hydraulic architecture in the kingdom.

Suffolk.
 Soil, agriculture, and productions.

Cattle.

Manufactures.

Fisheries and commerce.

Rivers and short canals.

Suffragan
||
Sugar.
Landed
property.

The landed property of the county is much divided. There are scarcely any estates so large as to create a decided political preponderance, and there is a larger number of proprietors occupying their own lands, of a value of from L.100 to L.400 per annum, than in any other county. Except in the heavy clay districts, the farms are generally large; and the tenants being possessed of ample capitals, the agricultural business is admirably conducted. There are neither mines nor mineral springs in this county. In the summer season sea-bathing attracts a considerable portion of company to the shore at Lowestoffe, Southwold, and some other spots, where every accommodation for such parties is provided.

Antiquities. Among the antiquities stand first the remains of the ancient Roman castle at Burgh, on the banks of the Yare. It is said to have been the ancient Garianonum, erected by Publius Ostorius Scapula, in the reign of the emperor Claudius. The walls, which are still standing, enclose a space 642 feet in length and 320 in breadth; they are fourteen feet in height and nine in thickness. The whole ground plan, including the wall, is more than five acres, and is capable of containing a cohort and a half; having been built to keep in subjection the Sceni, a people inhabiting Suffolk, Norfolk, Huntingdonshire, and Cambridge-shire. The most remarkable of the Saxon antiquities are the monastery at Bury St Edmund's, that of Framlingham, and several ancient churches.

Titles and
representa-
tion.

The following peers derive their titles from places in this county: Marquis Cornwallis; Earls of Suffolk, Orford, Euston, and Stradbroke; and Barons Rendlesham and Worlingham. The county has been formed into two divisions, the eastern and western, for the purpose of electing members to parliament, each division returning two. The elections for the eastern part are held at Ipswich; and the other polling places are Needham, Woodbridge, Framlingham, Saxmundham, Beccles, and Halesworth. The elections for the western part are held at Bury St Edmund's; and the other polling places are Wickham Brook, Lavenham, Stowmarket, Botesdale, Mildenhall, and Hadleigh. By the reform act the boroughs of Dunwich, Alborough, and Orford, which had each returned two members, have been disfranchised; and Eye, which likewise returned two, now returns only one. Ipswich, Bury St Edmund's, and Sudbury return two members as before.

The most remarkable seats among a very great number belonging to noblemen and gentlemen in this county are, Euston Hall, Duke of Grafton; Broom Hall, Sir E. Kerrison; Ickworth, Marquis of Bristol; Henham, Lord Stradbroke; Worlingham Hall, Lord Gosford; Boston Hall, Sir H. E. Banbury; Rendlesham, Lord Rendlesham; Benacre, Sir Thomas Gooch; Haveningham Hall, Lord Huntingfield; Sotterly Park, Miles Barm, Esq.; Flinton Hall, Alexander Adair, Esq.; Redgrove Hall, Admiral Wilson; Woolverston Park, Charles Berners, Esq.; Long Melford, Sir Hyde Parker; Shrubland Park, Sir William Middleton; and Tendring Hall, Sir Joseph Rowley.¹

SUFFRAGAN, an appellation given to simple bishops with regard to archbishops, on whom they depend, and to whom appeals lie from the bishops' courts. The same name is likewise given to a bishop who is occasionally appointed to assist the diocesan.

SUFFRAGE denotes a vote given in an assembly where something is deliberated on, or where a person is elected to an office or benefice.

SUGAR, a solid sweet substance, obtained from the juice of the sugar-cane; or, according to chemists, an essential salt, capable of crystallization, of a sweet and agree-

able flavour, and contained in a greater or less quantity in almost every species of vegetables, but most abundant in the sugar-cane. Sugar.

As the sugar-cane is the principal production of the West Indies, and the great source of their riches; as it is so important in a commercial view, from the employment which it gives to seamen, and the wealth which it opens for merchants, and besides is now become a necessary of life; it may justly be esteemed one of the most valuable plants in the world. From the few remains of the Grecian and Roman authors which have survived the ravages of time, we can find no proofs that the juice of the sugar-cane was known at a very early period. There can however be no doubt, that in those countries where it was indigenous, its value was not long concealed. It is not improbable that it was known to the ancient Jews; for there is some reason to suppose, that the Hebrew word קנה, which frequently occurs in the Old Testament, and by our translators is rendered sometimes *calamus*, and sometimes *sweet cane*, does in fact mean the sugar-cane. The first passage in which we have observed it mentioned is Exodus, xxx. 23, where Moses is commanded to make an ointment with myrrh, cinnamon, *kené*, and cassia. Now the *kené* does not appear to have been a native of Egypt, nor of Judea; for in Jeremiah, vi. 20, it is mentioned as coming from a far country. "To what purpose cometh there to me incense from Sæbea, and the sweet cane from a far country?" This is not true of the *calamus aromaticus*, which grows spontaneously in the Levant, as well as in many parts of Europe. If the cinnamon mentioned in the passage of Exodus quoted above was true cinnamon, it must have come from the East Indies, the only country in the world from which cinnamon is obtained. There is no difficulty therefore in supposing that the sugar-cane was exported from the same country. If any credit be due to etymology, it confirms the opinion that *kené* denotes the sugar-cane; for the Latin word *canna*, and the English word *cane*, are evidently derived from it. It is also a curious fact, that שֶׁכֶר, *sachar* or *sheker*, in Hebrew signifies *inebriation*, from which the Greek word *σάκχαρ* or *σακχαρίον*, *sugar*, is undoubtedly to be traced. Was proba-
bly known
to the an-
cient Jews.

The sugar-cane was first made known to the western parts of the world by the conquests of Alexander the Great. Strabo (lib. xv.) relates that Nearchus, his admiral, found it in the East Indies in the year 325 before Christ. It is evidently alluded to in a fragment of Theophrastus, preserved in Photius. Varro, who lived A. C. 68, describes it in a fragment quoted by Isidorus,² as a fluid pressed from reeds of a large size, which was sweeter than honey.³ Dioscorides, about the year 35 before Christ, says "that there is a kind of honey called *saccharon*, which is found in India and Arabia Felix. It has the appearance of salt, and is brittle when chewed. If dissolved in water, it is beneficial to the bowels, and stomachic; is useful in diseases of the bladder and kidneys; and when sprinkled on the eye, removes those substances that obscure the sight." This is the first account we have of its medicinal qualities. Galen often prescribed it as a medicine. Lucan (lib. iii. v. 237) relates, that an oriental nation in alliance with Pompey used the juice of the cane as a common drink.

Quique bibunt tenera dulces ab arundine succos.

Pliny says it was produced in Arabia and India, but that the best came from the latter country. It is also mentioned by Arrian, in his Periplus of the Red Sea, by the name of *σακχαρι* (*sacchari*), as an article of commerce from India to the Red Sea. Ælian,⁴ Tertullian,⁵ and Alexander Aphro-

¹ Kirby's Suffolk Traveller. Arthur Young's General View of the Agriculture of Suffolk. Views in Suffolk, by W. C. Brayley.

² Lib. xvii. cap. 3.

³ Matthioli Dios. cap. lxxv.

⁴ Nat. Hist.

⁵ De Judicio Dei.

Sugar. disæus,¹ mention it as a species of honey procured from canes.²

Is a native of the East Indies.

That the sugar-cane is an indigenous plant in some parts of the East Indies, we have the strongest reason to believe; for Thunberg found it in Japan, and has accordingly mentioned it as a native of that country in his *Flora Japonica*, published in 1784. Osbeck also found it in China in 1751. It may indeed have been transplanted from some other country; but as it does not appear from history that the inhabitants of Japan or China ever carried on any commerce with remote nations, it could only be conveyed from some neighbouring country. Marco Polo, a noble Venetian, who travelled into the east about the year 1250, found sugar in abundance in Bengal. Vasco de Gama, who doubled the Cape of Good Hope in 1497, relates that a considerable trade in sugar was then carried on in the kingdom of Calicut. On the authority of Dioscorides and Pliny, we should be disposed to admit that it is a native of Arabia, did we not find, on consulting Niebuhr's Travels, that this botanist has omitted it when enumerating the most valuable plants of that country. If it be a spontaneous production of Arabia, it must still flourish in its native soil. Mr Bruce found it in Upper Egypt. If we may believe the relation of Giovan Lioni, a considerable trade was carried on in sugar in Nubia in 1500. It abounded also at Thebes, on the Nile, and in the northern parts of Africa, about the same period.

Introduced into Europe probably during the crusades.

There is reason to believe that the sugar-cane was introduced into Europe during the crusades; expeditions which, however romantic in their plan, and unsuccessful in their execution, were certainly productive of many advantages to the nations of Europe. Albertus Aquensis, a monkish writer, observes that the Christian soldiers in the Holy Land frequently derived refreshment and support during a scarcity of provisions, by sucking the canes. This plant also flourished in the Morea, and in the islands of Rhodes and Malta, from which it was transported into Sicily. The date of this transaction it is not easy to ascertain; but we are sure that sugar was cultivated in that island previously to the year 1166; for Lafitau the Jesuit, who wrote a history of the Portuguese discoveries, mentions a donation made that year to the monastery of St Bennet, by William II., king of Sicily, of a mill for grinding sugar-canes, with all its rights, members, and appurtenances. From Sicily, where the sugar-cane still flourishes, on the sides of Mount Hybla, it was conveyed to Spain, Madeira, the Canary and Cape de Verd Islands, soon after they were discovered in the 15th century.³

Supposed by some not a native of America or the West Indies.

An opinion has prevailed that the sugar-cane is not a native of the western continent, or its adjacent islands the West Indies, but was conveyed thither by the Spaniards or Portuguese soon after the discovery of America by Columbus. From the testimony of Peter Martyr, in the third book of his first decade, composed during Columbus's second voyage, which commenced in 1493 and ended in 1495, it appears that the sugar-cane was known at that time in Hispaniola. It may be said that it was brought thither by Columbus, but for this assertion we have found no direct evidence; and though we had direct evidence, this would not prove that the sugar-cane was not an indigenous plant of the West Indies. There are authors of learning who, after investigating this subject with attention, do not hesi-

tate to maintain that it is a native both of the islands and of the continent of America.

Labat has supported this opinion with much appearance of truth;⁴ and, in particular, he appeals to the testimony of Thomas Gage, an Englishman, who visited New Spain in 1625. Gage enumerates sugar-canes among the provisions with which the Charaibes of Guadaloupe supplied his ship. "Now," says Labat, "it is a fact that the Spaniards had never cultivated an inch of ground in the smaller Antilles. Their ships commonly touched at those islands, indeed, for wood and water; and they left swine in the view of supplying with fresh provisions such of their countrymen as might call there in future; but it would be absurd in the highest degree to suppose that they would plant sugar-canes, and at the same time put hogs ashore to destroy them. Neither had the Spaniards any motive for bestowing this plant on islands which they considered as of no kind of importance, except for the purpose that has been mentioned; and to suppose that the Charaibes might have cultivated, after their departure, a production of which they knew nothing, betrays a total ignorance of the Indian disposition and character.

"But," continues Labat, "we have surer testimony, and from testimony such as proves, beyond all contradiction, that the sugar-cane is the natural production of America. For, besides the evidence of Francis Ximenes, who, in a treatise on American Plants, printed at Mexico, asserts that the sugar-cane grows without cultivation, and to an extraordinary size, on the banks of the river Plata, we are assured by Jean de Lery, a Protestant minister, who was chaplain in 1556 to the Dutch garrison in the fort of Coligny, on the river Janeiro, that he himself found sugar-canes in great abundance in many places on the banks of that river, and in situations never visited by the Portuguese. Father Hennepin and other voyagers bear testimony in like manner to the growth of the cane near the mouth of the Mississippi; and Jean de Laet to its spontaneous production in the island of St Vincent. It is not for the plant itself, therefore, but for the secret of making sugar from it, that the West Indies are indebted to the Spaniards and Portuguese; and these to the nations of the east." Such is the reasoning of Labat, which the learned Lafitau has pronounced incontrovertible; and it is greatly strengthened by recent discoveries, the sugar-cane having been found in many of the islands of the Pacific Ocean by our late illustrious navigator Captain Cook.

The sugar-cane, or *saccharum officinarum* of botanists, Description is a jointed reed, commonly measuring (the flag part not of the included) from three feet and a half to seven feet in height, sugar-cane. but sometimes rising to twelve feet. When ripe it is of a fine straw colour inclining to yellow, producing leaves or blades, the edges of which are finely and sharply serrated, and terminating in an arrow decorated with a panicle. The joints in one stalk are from forty to sixty in number, and the stalks rising from one root are sometimes very numerous. The young shoot ascends from the earth like the point of an arrow; the shaft of which soon breaks, and the two first leaves, which had been enclosed within a quadruple sheath of seminal leaves, rise to a considerable height.⁵

As the cane is a rank succulent plant, it must require a Soil most favourable to its growth.

¹ Lib. ii. prob. 79.

² For a more minute account of the history of sugar in the early and middle ages, the reader may consult a paper by Falconer, in the Manchester Transactions, vol. iv.

³ D'Orville's Travels.

⁴ "A field of canes, when standing, in the month of November, when it is in arrow or full blossom (says Mr Beckford in his Descriptive Account of the Island of Jamaica), is one of the most beautiful productions that the pen or pencil can possibly describe. It in common rises from three to eight feet or more in height; a difference of growth that very strongly marks the difference of soil or the varieties of culture. It is when ripe of a bright and golden yellow; and where obvious to the sun, is in many parts very beautifully streaked with red: the top is of a darkish green; but the more dry it becomes, from either an excess of ripeness or a continuance of drought, of a russet yellow, with long and narrow leaves depending; from the centre of which shoots up an arrow like a silver wand from two to six feet in height, and from the summit of which grows out a plume of white feathers, which are delicately fringed with lilac dye, and indeed is in its appearance not much unlike the tuft that adorns this particular and elegant tree."

⁵ Tom. iii. c. xv.

Sugar.

strong deep soil to bring it to perfection, perhaps indeed no soil can be too rich for this purpose. The soil which experience has found to be most favourable to the cultivation of it in the West Indies, is the dark-gray loam of St Christopher's, which is so light and porous as to be penetrable by the slightest application of the hoe. The under stratum is gravel from eight to twelve inches deep. Canes planted in particular spots in this island have been known to yield 8000 pounds of Muscovado sugar from a single acre. The average produce of the island for a series of years was 16,000 hogsheads of sixteen hundredweight, which is one half only of the whole cane-land, or 8500 acres. When annually cut, it gives nearly two hogsheads of sixteen hundredweight per acre for the whole of the land in ripe canes.

Next to the ashy loam of St Christopher's is the soil which in Jamaica is called *brick-mould*; not as resembling a brick in colour, but as containing such a due mixture of clay and sand as is supposed to render it well adapted for the use of the kiln. It is a deep, warm, and mellow, hazel earth, easily worked; and though its surface soon grows dry after rain, the under stratum retains a considerable degree of moisture in the driest weather; with this advantage, too, that even in the wettest season it seldom requires trenching. Plant-canes, by which are meant canes of the first growth, have been known in very fine seasons to yield two tons and a half of sugar per acre. After this may be reckoned the black mould of several varieties. The best is the deep black earth of Barbadoes, Antigua, and some other of the windward islands; but there is a species of this mould in Jamaica that is but little, if any thing, inferior to it, which abounds with limestone and flint on a substratum of soapy marle.¹ Black mould on clay is more common; but as the mould is generally shallow, and the clay stiff and retentive of water, this last sort of land requires great labour, both in ploughing and trenching, to render it profitable. When manured and properly pulverized, it becomes very productive. It is unnecessary to attempt a minute description of all the other soils which are found in these islands. There is, however, a peculiar sort of land on the north side of Jamaica, chiefly in the parish of Trelawney, that cannot be passed over unnoticed, not only on account of its scarcity, but its value; few soils producing finer sugars, or such as *answer so well in the pan*; an expression signifying a greater return of refined sugar than common. The land alluded to is generally of a red colour; the shades of which, however, vary considerably from a deep chocolate to a rich scarlet; in some places it approaches to a bright yellow, but it is everywhere remarkable, when first turned up, for a glossy or shining surface, and if wetted stains the fingers like paint.

Proper season for planting it.

As in every climate there is a season more favourable for vegetation than others, it is of great importance that plants for seed be committed to the ground at the commencement of this season. As the cane requires a great deal of moisture to bring it to maturity, the properest season for planting it is in the months of September and October, when the autumnal rains commence, that it may be sufficiently luxuriant to shade the ground before the dry weather sets in. Thus the root is kept moist, and the crop is ripe for the mill in the beginning of the ensuing year. Canes planted in the month of November, or later in the season, lose the advantage of the autumnal rains; and it often happens that dry weather in the beginning of the ensuing year retards their vegetation until the vernal or May rains set in, when they sprout both at the roots and the joints; so that by the time they are cut the field is loaded with unripe suckers instead of sugar-canes. A January plant, however,

commonly turns out well; but canes planted very late in the spring, though they have the benefit of the May rains, seldom answer expectation; for they generally come in unseasonably, and throw the ensuing crops out of regular rotation. They are therefore frequently cut before they are ripe; or, if the autumnal season sets in early, are cut in wet weather, which has probably occasioned them to spring afresh. In either case the effect is the same: the juice is unconcocted, and all the sap being in motion, the root is deprived of its natural nourishment, to the great injury of the ratoon. The chief objection to a fall plant is this, that the canes become rank and top-heavy at a period when violent rains and high winds are expected, and are therefore frequently lodged before they are fit to be cut.

Sugar.

The sugar-cane is propagated by the top-shoots, which are cut from the tops of the old canes. The usual method of planting in the West Indies is this. The quantity of land intended to be planted, being cleared of weeds and other encumbrances, is first divided into several plats of certain dimensions, commonly from fifteen to twenty acres each; the spaces between each plat or division are left wide enough for roads, for the convenience of carting, and are called *intervals*. Each plat is then subdivided, by means of a line and wooden pegs, into small squares of about three feet and a half. Sometimes, indeed, the squares are a foot larger, but this circumstance makes but little difference. The negroes are then placed in a row in the first line, one to a square, and directed to dig out with their hoes the several squares, commonly to the depth of five or six inches. The mould which is dug up being formed into a bank at the lower side, the excavation or cane-hole seldom exceeds fifteen inches in width at the bottom, and two feet and a half at the top. The negroes then fall back to the next line, and proceed as before. Thus the several squares between each line are formed into a trench of much the same dimensions with that which is made by the plough. An able negro will dig from 100 to 120 of these holes for his day's work of ten hours; but if the land has been previously ploughed and lain fallow, the same negro will dig nearly double the number in the same time.

The cane-holes or trench being now completed, whether by the plough or by the hoe, and the cuttings selected for planting, which are commonly the tops of the canes that have been ground for sugar (each cutting containing five or six gems), two of them are sufficient for a cane-hole of the dimensions described. These, being placed longitudinally in the bottom of the hole, are covered with mould about two inches deep, the rest of the bank being intended for future use. In twelve or fourteen days the young sprouts begin to appear, and as soon as they rise a few inches above the ground, they are, or ought to be, carefully cleared of weeds, and furnished with an addition of mould from the banks. This is usually performed by the hand. At the end of four or five months the banks are wholly levelled, and the spaces between the rows carefully hoe-ploughed. Frequent cleanings, while the canes are young, are indeed so essentially necessary, that no other merit in an overseer can compensate for the want of attention in this particular. A careful manager will remove at the same time all the lateral shoots or suckers that spring up after the canes begin to joint, as they seldom come to maturity, and draw nourishment from the original plants.

"In the cultivation of other lands, in Jamaica especially," says Mr Edwards, the elegant historian of the West Indies, whose superior excellence has induced us frequently to refer to him in the course of this article, "the plough has been introduced of late years, and in some few cases to great advantage; but it is not every soil or situation that

¹ Edwards's History of the West Indies, vol. ii.

Sugar. will admit the use of the plough, some lands being much too stony, and others too steep; and I am sorry I have occasion to remark, that a practice commonly prevails in Jamaica, on properties where this auxiliary is used, which would exhaust the finest lands in the world. It is that of ploughing, then cross-ploughing, round-ridging, and harrowing the same lands from year to year, or at least every other year, without affording manure. Accordingly it is found that this method is utterly destructive of the ratoon or second growth, and altogether ruinous. It is indeed astonishing that any planter of common reading or observation should be passive under so pernicious a system. Some gentlemen, however, of late manage better; their practice is to break up stiff and clayey land, by one or two ploughings, early in the spring, and give it a summer's fallow. In the autumn following, being then mellow and more easily worked, it is holed and planted by manual labour after the old method, which has been already described. But, in truth, the only advantageous system of ploughing in the West Indies is to confine it to the simple operation of holing, which may certainly be performed with much greater facility and despatch by the plough than by the hoe; and the relief which, in the case of stiff and dry soils, is thus given to the negroes, exceeds all estimation, in the mind of a humane and provident owner. On this subject I speak from practical knowledge. At a plantation of my own, the greatest part of the land which is annually planted is neatly and sufficiently laid into cane-holes, by the labour of one able man, three boys, and eight oxen, with the common single-wheeled plough. The ploughshare indeed is somewhat wider than usual; but this is the only difference, and the method of ploughing is the simplest possible. By returning the plough back along the furrow, the turf is alternately thrown to the right and to the left, forming a trench seven inches deep, about two feet and a half wide at the top, and one foot wide at the bottom. A space of eighteen or twenty inches is left between each trench, on which the mould being thrown by the share, the banks are properly formed, and the holing is complete. Thus the land is not exhausted by being too much exposed to the sun; and in this manner a field of twenty acres is holed with one plough, and with great ease, in thirteen days. The plants are afterwards placed in the trench as in the common method where manual labour alone is employed."¹

Canes named according to the age of their roots.

Manures employed.

In most parts of the West Indies it is usual to hole and plant a certain proportion of the cane-land, commonly one third, in annual rotation. Canes of the first year's growth are called *plant-canes*, as has been already observed. The sprouts that spring from the roots of the canes that have been previously cut for sugar are called *ratons*; the first yearly returns from their roots are called *first ratons*, the second year's growth *second ratons*.

Mr Edwards informs us, that the manure generally used is a compost, formed, 1st, of the vegetable ashes drawn from the fires of the boiling and still-houses; 2dly, feculencies discharged from the still-house, mixed up with rubbish of buildings, white-lime, &c.; 3dly, refuse, or field-trash, i. e. the decayed leaves and stems of the cane, so called in contradistinction to cane-trash, reserved for fuel; 4thly, dung, obtained from the horse and mule stables, and from moveable pens, or small enclosures made by posts and rails, occasionally shifted upon the lands intended to be planted, and into which the cattle are turned at night; 5thly, good mould, collected from gullies and other waste places, and thrown into the cattle-pens.

The sugar-cane destroyed by monkeys. The sugar-cane is liable to be destroyed by monkeys, rats, and insects. The upland plantations suffer greatly from monkeys. These creatures, which now abound in

the mountainous parts of St Christopher's, were first brought thither by the French, when they possessed half that island. They come down from the rocks in silent parties by night, and having posted sentinels to give the alarm if any thing approaches, they destroy incredible quantities of the cane, by their gambols as well as their greediness. It is in vain to set traps for these creatures, however baited; and the only way to protect the plantation, and destroy them, is to set a numerous watch, well armed with fowling-pieces, and furnished with dogs. The negroes will perform this service cheerfully, for they are very fond of monkeys as food. Father Labat affirms they are very delicious, but the white inhabitants of St Christopher's never eat them.

The low-land plantations suffer as much by rats as those rats, on the mountains do from monkeys; but the rats, no more than the monkeys, are natives of the place. They came with the shipping from Europe, and breed in the ground under loose rocks and bushes: the field negroes eat them greedily, and they are said to be publicly sold in the markets at Jamaica. To free the plantations from these vermin, the breed of wild cats should be encouraged, and snakes suffered to multiply unmolested: they may also be poisoned with arsenic, and the rasped root of the cassava made into pellets, and plentifully scattered over the grounds. This practice is however dangerous; for as the rats, when thus poisoned, become exceedingly thirsty, they run in droves to the neighbouring streams, which they poison as they drink, and the cattle grazing on the banks of these polluted waters have frequently perished by drinking after them. It is safer therefore to make the pellets of flour, kneaded with the juice of the nightshade, the scent of which will drive them away though they will not eat it. There is an East Indian animal called *mungoes*, which bears a natural antipathy to rats; and if this animal was introduced into our sugar islands, it would probably extirpate the whole race of these noxious vermin. The *formica omnivora* of Linnæus, the carnivorous ant, which is called in Jamaica the *raffle's ant*, would soon clear a sugar-plantation of rats.

The sugar-cane is also subject to a disease which no fore-sight can obviate, and for which human wisdom has hitherto in vain attempted to find a remedy. This disease is called the *blast*, and is occasioned by a species of *aphis*. When this happens, the fine, broad, green blades become sickly, dry, and withered; they soon afterwards appear stained in spots; and if these spots are carefully examined, they will be found to contain innumerable eggs of an insect like a bug, which are soon quickened, and cover the plants with the vermin. The juice of the canes thus affected becomes sour, and no future shoot issues from the joints. Ants also concur with the bugs to spoil the plantation, and against these evils it is hard to find a remedy.

The crops of sugar-canes do not ripen precisely at the same period in all the colonies. In the Danish, Spanish, and Dutch settlements, they begin in January, and continue till October. This method does not imply any fixed season for the maturity of the sugar-cane. The plant, however, like others, must have its progress; and it has been justly observed to be in flower in the months of November and December. From the custom which these nations have adopted of continuing to gather their crops for ten months without intermission, it must necessarily follow that they cut some canes which are not ripe enough, and others which are too ripe, and then the fruit has not the requisite qualities. The time of gathering them should be at a fixed season, and probably the months of March and April are the fittest for it; because all the sweet fruits are ripe at that time, while the sour ones do not arrive at a state of maturity till the months of July and August.

The English cut their canes in March and April; but

¹ Edwards's History of the West Indies, vol. ii.

Sugar. they are not induced to do this on account of their ripeness. The drought that prevails in their islands renders the rains which fall in September necessary to their planting; and as the canes are eighteen months in growing, this period always brings them to the precise point of maturity.¹ **a season of festivity.** "The time of crop in the sugar islands," says Mr Edwards, "is the season of gladness and festivity to man and beast. So palatable, salutary, and nourishing, is the juice of the cane, that every individual of the animal creation, drinking freely of it, derives health and vigour from its use. The meagre and sickly among the negroes exhibit a surprising alteration in a few weeks after the mill is set in action. The labouring horses, oxen, and mules, though almost constantly at work during this season, yet, being indulged with plenty of the green tops of this noble plant, and some of the scummings from the boiling-house, improve more than at any other period of the year. Even the pigs and poultry fatten on the refuse. In short, on a well-regulated plantation, under a humane and benevolent director, there is such an appearance during crop-time of plenty and busy cheerfulness, as to soften, in a great measure, the hardships of slavery, and induce a spectator to hope, when the miseries of life are represented as insupportable, that they are sometimes exaggerated through the medium of fancy."

The canes when cut are sent to the mill.

The plants being cut, the branches at the top are given to the cattle for food; the top-shoot, which is full of eyes, is preserved for planting. The canes are cut into pieces about a yard long, tied up in bundles, and carried in carts to the mill, where they are bruised, and the juice is extracted from them. The mill consists principally of three upright iron-plated rollers or cylinders, from thirty to forty inches in length, and from twenty to twenty-five inches in diameter; and the middle one, to which the moving power is applied, turns the other two by means of cogs. Between these rollers, the canes, being previously cut short, and tied into bundles, are twice compressed; for, having passed through the first and second rollers, they are turned round the middle one by a circular piece of frame-work or screen, called in Jamaica the *dumb-returner*, and forced back through the second and third; an operation which squeezes them completely dry, and sometimes even reduces them to powder. The cane-juice is received in a leaden bed, and thence conveyed into a vessel called the *receiver*. The refuse, or macerated rind, of the cane, which is called *cane-trash*, in contradistinction to *field-trash*, serves for fuel to boil the liquor.

The juice extracted from them.

The juice as it flows from the mill, taken at a medium, contains eight parts of pure water, one part of sugar, and one part consisting of coarse oil and mucilaginous gum, with a portion of essential oil.

Vessels used for purifying it are,

As this juice has a strong disposition to fermentation, it must be boiled as soon as possible. There are some water-mills that will grind with great ease canes sufficient for thirty hogsheads of sugar in a week. It is necessary to have boiling vessels, or clarifiers, that will correspond in dimensions to the quantity of juice flowing from the receiver. These clarifiers are commonly three in number, and are sometimes capable of containing 1000 gallons each; but it is more usual to see them of 300 or 400 gallons each. Besides the clarifiers which are used for the first boiling, there are generally four coppers or boilers. The clarifiers are placed in the middle or at one end of the boiling-house. If at one end, the boiler called the *teache* is placed at the other, and several boilers, generally three, are ranged between them. The *teache* is ordinarily from seventy to 100 gallons, and the boilers between the clarifiers and *teache* diminish in size from the first to the last. Where the clarifiers are in the middle, there is usually a set of three

Sugar. boilers on each side, which constitute in effect a double boiling-house. On very large estates this arrangement is found useful and necessary. The objection to so great a number is the expense of fuel; to obviate which, in some degree, the three boilers on each side of the clarifiers are commonly hung to one fire.

The juice runs from the receiver along a wooden gutter the clarifier, lined with lead into the boiling-house, where it is received into one of the clarifiers. When the clarifier is filled, a fire is lighted, and a quantity of Bristol quicklime in powder, which is called *temper*, is poured into the vessel. The use of the lime is to unite with the superabundant acid, of which, for the success of the process, it is necessary to get rid. The quantity sufficient to separate the acid must vary according to the strength of the quicklime and the quality of the liquor. Some planters allow a pint of lime to every 100 gallons of liquor; but Mr Edwards thinks that little more than half the quantity is a better medium proportion, and, even then, that it ought to be dissolved in boiling water, that as little of it as possible may be precipitated. The heat is suffered gradually to increase till it approaches within a few degrees of the heat of boiling water, that the impurities may be thoroughly separated. But if the liquor were suffered to boil with violence, the impurities would again incorporate with it. It is known to be sufficiently heated when the scum begins to rise in blisters, which break into white froth, and appear generally in about forty minutes. The fire is then suddenly extinguished by means of a damper, which excludes the external air; and the liquor is allowed to remain about an hour undisturbed, during which period the impurities are collected in scum on the surface. The juice is then drained off either by a syphon or a cock; the scum, being of a tenacious gummy nature, does not flow out with the liquor, but remains behind in the clarifier. The liquid juice is conveyed from the clarifier by a gutter into the evaporating boiler, commonly termed the *grand copper*; and if it has been obtained from good canes it generally appears transparent.

In the evaporating boiler, which should be large enough and four to receive the contents of the clarifier, the liquor is allowed to boil; and as the scum rises it is taken off. The scumming and evaporation are continued till the liquor becomes finer and thicker, and so far diminished in bulk that it may be easily contained in the second copper. When put into the second copper, it is nearly of the colour of Madeira wine; the boiling and scumming are continued, and if the impurities be considerable, a quantity of lime-water is added. This process is carried on till the liquor be sufficiently diminished in quantity to be contained in the third copper. After being purified a third time, it is put into the fourth copper, which is called the *teache*, where it is boiled and evaporated till it is judged sufficiently pure to be removed from the fire. In judging of the purity of the liquor, many of the negroes, says Mr Edwards, guess solely by the eye (which by long habit they do with great accuracy), judging by the appearance of the grain on the back of the ladle: but the practice most in use is to judge by what is called the *touch*, *i. e.* taking up with the thumb a small portion of the hot liquor from the ladle, and, as the heat diminishes, drawing with the forefinger the liquid into a thread. This thread will suddenly break, and shrink from the thumb to the suspended finger, in different lengths, according as the liquor is more or less boiled. The proper boiling height for strong muscovado sugar is generally determined by a thread of a quarter of an inch long. It is evident that certainty in this experiment can be attained only by long habit, and that no

¹ The account given in the text concerning the time when the sugar-canes are collected, we have taken from the Abbé Raynal's History of the Trade and Settlements of the East and West Indies; but Mr Cazaud observes, that in February, March, and April, all the canes, whatever be their age, are as ripe as the nature of the soil ever allows them to be. (Philosophical Transactions, vol. lxi.)

Sugar. verbal precepts will furnish any degree of skill in a matter depending wholly on constant practice.

After being clarified it is cooled, granulated, and freed from its molasses. The juice being thus purified by passing through the clarifier and four coppers, it is poured into coolers, which are usually six in number. The removal from the teache to the cooler is called *striking*. The cooler is a shallow wooden vessel, seven feet long, from five to six wide, about eleven inches deep, and capable of containing a hogshead of sugar. As the liquor cools, the sugar grains, that is, collects into an irregular mass of imperfect crystals, separating itself from the molasses. It is then removed from the cooler and conveyed to the curing house, where the molasses drain from it. For receiving them there is a large cistern, the sloping sides of which are lined with boards. Directly above the cistern a frame of joist-work without boarding is placed, on which empty hogsheads without heads are ranged. The bottoms of these hogsheads are pierced with eight or ten holes, in each of which the stalk of a plantain leaf is fixed, so as to project six or eight inches below the joists, and rise a little above the top of the hogshead. The hogshead being filled with the contents of the cooler, consisting of sugar and molasses, the molasses being liquid, drain through the spongy stalk, and drop into the cistern. After the molasses are drained off, the sugar becomes pretty dry and fair, and is then called *muscovado* or *raw sugar*.

We have described the process for extracting sugar, which is generally adopted in the British West India islands, according to the latest improvements; and have been anxious to present it to our readers in the simplest and most perspicuous form, that it might be intelligible to every person; and have therefore avoided to mention the observations and proposed amendments of those who have written on this subject. Had we done so, we should have swelled the present article to too great a size, without accomplishing the purpose which we have in view; for our intention is not to instruct the planters, but to give a distinct account of the most approved methods which the planters have generally adopted. But though we judge it useless to trouble our readers with all the little varieties in the process which different persons employ, we flatter ourselves it will not be disagreeable to learn by what methods the French make their sugar purer and whiter than ours. A quantity of sugar from the cooler is put into conical pans or earthen pots, called by the French *formes*, having a small perforation at the apex, which is kept closed. Each cone, reversed on its apex, is supported in another earthen vessel. The syrup is stirred together, and then left to crystallize. At the end of fifteen or sixteen hours, the hole in the point of each cone is opened, that the impure syrup may run out. The base of the sugar-loaves is then taken out, and white pulverized sugar substituted in its stead; which being well pressed down, the whole is covered with clay moistened with water. This water filters through the mass, carrying with it the syrup which was mixed with the sugar, but which by this management flows into a pot substituted in the place of the first. This second fluid is called *fine syrup*. Care is taken to moisten and keep the clay to a proper degree of softness as it becomes dry. The sugar-loaves are afterwards taken out, and dried in a stove for eight or ten days; after which they are pulverized, packed, and exported to Europe, where they are still further purified. The reason assigned why this process is not universally adopted in the British sugar islands is this, that the water which dilutes and carries away the molasses dissolves and carries with it so much of the sugar, that the difference in quality does not pay for the difference in quantity. The French planters probably thought otherwise, upwards of 400 of the plantations of St Domingo having had the necessary apparatus for claying and actually carrying on the system.

Method of purifying used by the French.

The art of refining sugar was first made known to the Europeans by a Venetian, who is said to have received 100,000 crowns for the invention. This discovery was made before the new world was explored; but whether it was an invention of the person who first communicated it, or whether it was conveyed from China, where it had been known for a considerable time before, cannot now perhaps be accurately ascertained. We find no mention made of the refining of sugar in Britain till the year 1659, though it probably was practised several years before; for in the Portuguese island of St Thomas in 1642 there were seventy-four sugar ingenios, each having upwards of two hundred slaves.

The sugar which undergoes the operation of refining in Europe is either raw sugar, sometimes called *muscovado*, or *cassonado*, which is raw sugar in a purer state. The raw sugar generally contains a certain quantity of molasses as well as earthy and feculent substances. The *cassonado*, by the operation of earthing, is freed from its molasses. As the intention of refining these sugars is to give them a higher degree of whiteness and solidity, it is necessary for them to undergo other processes. The first of these is called *clarification*. It consists in dissolving the sugar in a certain proportion of lime-water, adding a proper quantity of bullock's blood, and exposing it to heat in order to remove the impurities which still remain. The heat is increased very gradually till it approach that of boiling water. By the assistance of the heat, the animal matter which was thrown in coagulates, at the same time that it attracts all the solid feculent and earthy matter, and raises it to the surface in the appearance of a thick foam of a brownish colour. As the feculencies are never entirely removed by a first process, a second is necessary. The solution is therefore cooled to a certain degree by adding some water; then a fresh quantity of blood, but less considerable than at first, is poured in. The fire is renewed, and care is taken to increase the heat gently as before. The animal substance seizes on the impurities which remain, collects them on the surface, and they are then skimmed off. The same operation is repeated a third and even a fourth time, but no addition, except water, is made to the liquor. If the different processes have been properly conducted, the solution will be freed from every impurity, and appear transparent. It is then conveyed by a gutter into an oblong basket about sixteen inches deep, lined with a woollen cloth; and after filtering through this cloth, it is received in a cistern or copper which is placed below.

The solution being thus clarified, it undergoes a second general operation, called *evaporation*. Fire is applied to the copper into which the solution was received, and the liquid is boiled till it has acquired the proper degree of consistency. A judgment is formed of this by taking up a small portion of the liquid and drawing it into a thread. When, after this trial, it is found sufficiently viscous, the fire is extinguished, and the liquid is poured into coolers. It is then stirred violently by an instrument called an *oar*, from the resemblance it bears to the oar of a boat. This is done in order to diminish the viscosity, and promote what is called the *granulation*, that is, the forming of it into grains or imperfect crystals. When the liquid is properly mixed and cooled, it is then poured into moulds of the form of a sugar-loaf. These moulds are ranged in rows. The small ends, which are lowest, are placed in pots; and they have each of them apertures stopped up with linen for filtering the syrup, which runs from the moulds into the pots. The liquor is then taken out slowly in ladlefuls from the coolers, and poured into the moulds. When the moulds are filled, and the contents still in a fluid state, it is necessary to stir them, that no part may adhere to the moulds, and that the small crystals which are just formed may be equally diffused through the whole mass. When sugar is completely crystallized, the linen is taken away from the apertures in the

Sugar. The art of refining sugar introduced by a Venetian.

In refining, it is mixed with lime-water and bullock's blood, and exposed to heat.

Then freed from its remaining impurities by evaporation.

Afterwards poured into moulds, where the syrup is drained from it.

Sugar.

moulds, and the syrup, or that part which did not crystallize, descends into the pots in which the moulds are placed. After this purgation the moulds are removed and fixed in other pots, and a stratum of fine white clay diluted with water is laid on the upper part of the loaf. The water descending through the sugar by its own weight, mixes with the syrup which still remains in the body of the loaf, and washes it away. When the clay dries, it is taken off, and another covering of moist clay put in its place; and if it be not then sufficiently washed, a third covering of clay is applied. After the loaves have stood some days in the moulds, and have acquired a considerable degree of firmness and solidity, they are taken out and carried to a stove, where they are gradually heated to the 50° of Reaumur (64° of Fahrenheit), in order to dissipate any moisture which may be still confined in them. After remaining in the stove eight days, they are taken out; and after cutting off all discolouring specks, and the head if still wet, they are wrapped in blue paper, and are ready for sale. The several syrups collected during the different parts of the process, treated in the same manner which we have just described, afford sugars of inferior quality; and the last portion, which no longer affords any sugar, is sold by the name of *molasses*.

Lastly exposed to a certain degree of heat.

In what the beauty of sugar consists; how farther refined.

How sugar-candy is made.

The beauty of refined sugar, when formed into loaves, consists in whiteness, joined to a smallness of grain; in being dry, hard, and somewhat transparent. The process which we have described above refers to sugar once refined; but some more labour is necessary to produce double-refined sugar. The principal difference in the operation is this; the latter is clarified by white of eggs instead of blood, and fresh water in place of lime-water.

Sugar-candy is the true essence of the cane formed into large crystals by a slow process. When the syrup is well clarified, it is boiled a little, but not so much as is done in the process for making common sugar. It is then placed in old moulds, having their lower ends stopped with linen, and crossed at little distances with small twigs to retain the sugar as it crystallizes. The moulds are then laid in a cool place. In proportion as the syrup cools, crystals are formed. In about nine or ten days the moulds are carried to the stove, and placed in a pot; but the linen is not removed entirely, so that the syrup falls down slowly in drops. When the syrup has dropped away, and the crystals of the sugar-candy are become dry, the moulds are taken from the stove, and broken in pieces to disengage the sugar, which adheres strongly to the sides of the mould. If the syrup has been coloured with cochineal, the crystals take a slight taint of red; if indigo has been mixed, they assume a bluish colour. If it be desired to have the candy perfumed, the essence of flowers or amber may be dropped into the moulds along with the syrup.

The average quantity of sugar imported into Great Britain and Ireland during the last twenty years ending with 1837 is 4,486,014 cwts.; the quantity imported in 1837 was 4,482,578 cwts., which is somewhat under the average of the preceding nineteen years, while the population may be assumed to have increased at least twenty per cent. during the same period. From these facts we may fairly assume, that if the duty on sugar were reduced so as to bring the price within the reach of the poorer classes, the demand would greatly increase.

Sugar was imported into England in the fourteenth century, but in small quantities. The demand, however, increased very rapidly, and the consumption of this important necessary of life is now about twenty times greater than it was in the beginning of last century.

In 1700 it was 22,000,000 lbs.

... 1754 119,320,000 ...

... 1790 181,500,000 ...

... 1807 255,098,450 ...

... 1837 432,938,608 ...

Taking the aggregate population of the united kingdom in 1837 at twenty-four millions and a half, this gives to each individual just sixteen pounds per annum; a proportion very far below what might be expected were the price reduced.

An Account of the Quantity of Sugar imported into the United Kingdom, distinguishing Great Britain from Ireland, and specifying the Countries whence the Imports were received; together with a Statement of the Quantities and Descriptions cleared from the Warehouses and retained for Consumption, the Rates of Duty and Drawback, the Gross Amount of Duty, the Sum paid for Drawback, &c., and the Net Amount of Revenue, with the Gazette Average Prices, at the end of each Quarter of the Year 1837.

Places whence imported.	Quantities imported into		
	Great Britain.	Ireland.	United Kingdom.
	Cwts. qrs. lbs.	Cwts. qrs. lbs.	Cwts. qrs. lbs.
British Colonies and Plantations in America, viz.—			
Antigua.....	56,360 0 2	5,810 1 2	62,170 1 4
Barbadoes.....	413,287 2 21	32,425 1 23	445,713 0 16
Dominica.....	33,723 2 10	...	33,723 2 10
Grenada.....	161,921 2 20	...	161,921 2 10
Jamaica.....	901,078 2 15	3,221 0 3	904,299 2 18
Montserrat....	5,694 3 24	...	5,694 3 24
Nevis.....	24,269 0 0	...	24,269 0 0
St Christopher.	72,266 2 16	1,003 0 2	73,269 2 18
St Lucia.....	31,235 3 9	20,194 2 0	51,430 1 9
St Vincent.....	201,191 1 21	...	201,191 1 21
Tobago.....	90,803 0 25	...	90,803 0 25
Tortola.....	13,534 0 5	...	13,534 0 5
Trinidad.....	224,873 1 2	70,493 3 1	295,367 0 3
Demerara.....	705,637 3 18	87,214 0 4	792,851 3 22
Berbice.....	148,836 0 5	1,699 3 14	150,535 3 19
Honduras....	0 3 21	...	0 3 21
British North American Colonies.....	2,364 0 17	1 1 18	2,365 2 7
West Coast of Africa.....	1 3 11	...	1 3 11
Mauritius.....	537,454 3 17	...	537,454 3 17
British Possessions in the East Indies, viz.—			
East India Company's Territories, exclusive of			
Singapore.....	297,923 3 10	...	297,923 3 10
Singapore.....	5,019 0 26	...	5,019 0 26
Ceylon.....	2 0 0	...	2 0 0
Siam.....	18,805 3 6	...	18,805 3 6
Java.....	2,877 3 13	...	2,877 3 13
Philippine Islands.....	49,118 1 12	...	49,118 1 12
China.....	0 0 2	...	0 0 2
New South Wales.....	1,042 2 5	...	1,042 2 5
Foreign Colonies in the West Indies, viz.—			
Cuba.....	125,985 0 26	...	125,985 0 26
St Thomas.....	308 3 0	...	308 3 0
United States of America.....	1,667 0 12	...	1,667 0 12
Mexico.....	0 0 4	...	0 0 4
Columbia.....	533 1 5	...	533 1 5
Brazil.....	110,216 1 26	...	110,216 1 26
States of the Rio de la Plata	0 0 11	...	0 0 11
Chili.....	0 0 10	...	0 0 10
Peru.....	7,993 0 24	...	7,993 0 24
Europe.....	14,485 0 21	...	14,485 0 21
Total.....	4,260,514 3 24	222,063 1 11	4,482,578 1 7
Total in 1836 ..	4,411,527 0 8	237,633 3 27	4,649,161 0 7

Sugat Suicide.	Quantity cleared for consumption in the united kingdom.		
	Cwts.	qrs.	lbs.
Of the British plantations.....	3,562,778	3	19
Of Mauritius.....	522,360	3	23
Of the East Indies.....	270,078	0	10
Of the foreign plantations.....	35	2	7
Total	4,355,253	2	3
Quantity retained for consumption in the united kingdom.....			
	3,954,809	3	3
Gross amount of duty.			
Great Britain.....	L.4,874,162	4	3
Ireland.....	395,973	7	6
United kingdom.....	L.5,270,135	11	9
Drawback paid on exportation.			
Great Britain.....	L.497,419	3	4
Ireland.....	113	10	5
United kingdom.....	L.497,532	13	9
Repayments on over-entries, &c.			
Great Britain.....	L.11,936	0	11
Ireland.....	102	5	6
United kingdom.....	L.12,038	6	5
Net amount of revenue.			
Great Britain.....	L.4,364,807	0	0
Ireland.....	395,757	11	7
United kingdom.....	L.4,760,564	11	7
Rates of duty per cwt.			
British plantations and Mauritius.....	L.1	4	0
Any British possessions in the East Indies into which the importation of foreign sugar is prohibited.....	1	4	0
Of other British possessions in the East Indies.....	1	12	0
Foreign.....	3	3	0
Average price per cwt. according to the London Gazette.			
March 1837.....	L.1	18	0 $\frac{1}{4}$
June.....	2	1	6 $\frac{1}{2}$
September.....	2	3	7 $\frac{1}{4}$
December.....	1	15	5 $\frac{3}{4}$

SUGAT, a town of Asia Minor, in the pachalic of Bursa, supposed to be on the site of the ancient Tottarium. The houses are generally built of mud and wood, two stories high, with projecting verandahs, and roofed with common red tile. It is remarkable for the tomb of Ali Osman, held in high respect by the natives.

SUGGOWLY, a town of Hindustan, in the province of Bahar, district of Bettiah. It is situated on the Boora Gunduck river, and it carries on a considerable trade in timber, floated down from the northern hills. Long. 85. 5. E. Lat. 26. 43. N.

SUIATOI Nos, or HOLY CAPE, a cape of Asiatic Russia, in the province of Irkoutsk, between the rivers Yana and Indigirka, on the coast of the Frozen Ocean. Long. 39. 30. E. Lat. 68. 30. N.

SUICIDE, the crime of self-murder, or the person who commits it. We have often wished to see a history of crimes drawn up by a man of ability and research. In this history we would propose that the author should de-

scribe the crimes peculiar to different nations in the different stages of society, and the changes which they undergo in the progress of civilization. After having arranged the historical facts, he might, by comparing them with the religion and the knowledge of the people, deduce some important general conclusions, which would lead to a discovery of the cause of crimes, and of the remedy most proper to be applied. Some crimes are peculiar to certain stages of society, some to certain nations. Suicide is one of those crimes which we are led to believe not common among savage nations. The first instances recorded of it in the Jewish history are those of Saul and Ahitophel; for we do not think the death of Samson a proper example. We have not reason to suppose that it became common among the Jews till their wars with the Romans, when multitudes slaughtered themselves that they might not fall alive into the hands of their enemies. But at this period the Jews were a most desperate and abandoned race of men, had corrupted the religion of their fathers, and rejected that pure system which their promised Messiah came to announce.

When this crime became remarkable among the Greeks, we have not been able to discover; but it was forbidden by Pythagoras, as we learn from Athenæus, by Socrates and Aristotle, and by the Theban and Athenian laws. In the earliest ages of the Roman republic it was seldom committed; but when luxury and the Epicurean and Stoical philosophy had corrupted the simplicity and virtue of the Roman character, they then began to seek shelter in suicide, from their misfortunes or the effects of their own vices.

The religious principles of the Brahmins of India led them to admire suicide on particular occasions as honourable. Accustomed to abstinence, mortification, and the contempt of death, they considered it as a mark of weakness of mind to submit to the infirmities of old age. We are informed that the modern Gentoos, who still in most things conform to the customs of their ancestors, are frequently, when old and infirm, brought to the banks of rivers, particularly to those of the Ganges, that they may die in its sacred streams, which they believe can wash away the guilt of their sins. But the maxims of the Brahmins, which have encouraged this practice, we are assured by Mr Holwell, are a corruption of the doctrines of the Shaster, which positively forbid suicide under the severest punishment. The practice which religion or affection has established among the Gentoos, for women at the death of their husbands to burn themselves alive on the funeral pile, we do not think ought to be considered as suicide, as we are not anxious to extend the meaning of the word; for were we to extend it thus far, it would be as proper to apply it to those who choose rather to die in battle than make their escape at the expense of their honour. Thus we should condemn as suicides the brave Spartans who died at Thermopylæ in defence of their country. According to the Gentoos laws, "it is proper for a woman after her husband's death to burn herself in the fire with his corpse. Every woman who thus burns shall remain in paradise with her husband three crore and fifty lacs of years. If she cannot, she must in that case preserve an inviolable chastity. If she remain chaste, she goes to paradise; and if she do not preserve her chastity, she goes to hell."

A custom similar to this prevailed among many nations on the continent of America. When a chief died, a certain number of his wives, of his favourites, and of his slaves, were put to death, and interred together with him, that he might appear with the same dignity in his future station, and be waited upon by the same attendants. This persuasion was so deeply rooted, that many of their retainers offered themselves as victims; and the same custom prevails in many of the negro nations in Africa.

Suicide.

Suicide.

If we may rely on the historians of Japan, voluntary death is common in that empire. The devotees of the idol Amida drown themselves in his presence, attended by their relations and friends, and several of the priests, who all consider the devoted person as a saint, who is gone to everlasting happiness. Such being the supposed honours appropriated to a voluntary death, it is not surprising that the Japanese anxiously cherish a contempt of life. Accordingly it is a part of the education of their children "to repeat poems in which the virtues of their ancestors are celebrated, an utter contempt of life is inculcated, and suicide is set up as the most heroic of actions."

A notion seems also to have prevailed among the ancient Scythian tribes, that it was pusillanimous and ignoble for a man whose strength was wasted with disease or infirmity, so as to be useless to the community, to continue to live. It was reckoned an heroic action voluntarily to seek that death which he had not the good fortune to meet in the field of battle. Perversion of moral feeling does not spring up, we hope, spontaneously in any nation, but is produced by some peculiarities of situation. A wandering people like the Scythians, who roamed about from place to place, might often find it impossible to attend the sick, or to supply from their precarious store the wants of the aged and infirm. The aged and infirm themselves, no longer able to support the character of warriors, would find themselves unhappy. In this way the practice of putting to death such persons as were useless to the community might originate, and afterwards be inculcated as honourable; but he who put an end to his infirmities by his own hand obtained a character still more illustrious.

The tribes of Scandinavia, which worshipped Odin, the "father of slaughter," were taught, that dying in the field of battle was the most glorious event that could befall them. This was a maxim suited to a warlike nation. In order to establish it more firmly in the mind, all were excluded from Odin's feast of heroes who died a natural death. In Asgardia stood the hall of Odin, where, seated on a throne, he received the souls of his departed heroes. This place was called *Valhalla*, signifying "the hall of those who died by violence." Natural death being thus deemed inglorious, and punished with exclusion from *Valhalla*, the paradise of Odin, he who could not enjoy death in the field of battle was led to seek it by his own hands when sickness or old age began to assail him. In such a nation suicide must have been very common.

As suicide prevailed much in the decline of the Roman empire, when luxury, licentiousness, profligacy, and false philosophy, pervaded the world, so it continued to prevail even after Christianity was established. The Romans, when they became converts to Christianity, did not renounce their ancient prejudices and false opinions, but blended them with the new religion which they embraced. The Gothic nations, also, who subverted the Roman empire, while they received the Christian religion, adhered to many of their former opinions and manners. Among other criminal practices which were retained by the Romans and their conquerors, that of suicide was one; but the principles from which it proceeded were explained so as to appear more agreeable to the new system which they had espoused. It was committed either to secure from the danger of apostasy, to procure the honour of martyrdom, or to preserve the crown of virginity.

When we descend to modern times, we lament to find so many instances of suicide among the most polished nations, who have the best opportunities of knowing the atrocity of that unnatural crime. The English have long been reproached by foreigners for the frequent commission of it;

and the "gloomy month of November" has been stigmatized as the season when it is most common. But this disgraceful imputation, we think, may be justly attributed, not to the greater frequency of the crime in England than in other countries, but to the custom of publishing in the newspapers every instance of suicide which is known.

It might lead to some interesting conclusions to compare together, not only the number of suicides in different countries, but also the rank and principles, the sex and age, of those unhappy persons by whom it has been committed. Mercier says, that at Paris it was the lower ranks who were most commonly guilty of it; that it was mostly committed in garrets or hired lodgings; and that it proceeded from poverty and oppression. A great many, he says, wrote letters to the magistrates before their death. Mr Moore's correspondent from Geneva informed him, that from the year 1777 to 1787 more than 100 suicides were committed in Geneva; that two thirds of these unfortunate persons were men; that few of the clerical order have been known to commit it; and that it is not so much the end of an immoral, irreligious, dissipated life, as the effect of melancholy and poverty.¹

Humanity would in most cases dispose us to conclude that suicide is the effect of insanity, were there not so many instances of cool deliberate self-murder. That suicide is an unnatural crime, which none but a madman would commit, compassion indeed may suppose; but the murder of a wife, a father, or a child, are also unnatural; yet compassion does not teach us in all cases to ascribe such a crime to madness. Passion may often arise to such a height of outrage as to be scarcely distinguishable from madness in its symptoms and its effects; yet we always make a distinction between that madness which arises from disease and that which is owing to a violent perturbation of mind. If a person be capable of managing his worldly affairs, of making a will, and of disposing of his property, immediately before his death, or after he formed the resolution of dying by his own hands, such a man is not to be considered as insane.

But though a regard for truth prevents us from ascribing suicide in all cases to insanity, we must ascribe it either to insanity or to vicious passion. These two divisions, we imagine, will comprehend every species of it, whether arising from melancholy, *tedium vitæ* or *ennui*, disappointment in schemes of ambition or love, pride, gaming, or a desire to avoid the shame of a public execution; passions which are often increased by false views of God, of man, and of a future state, arising from deism and infidelity. If these be the causes of suicide in modern times, what a disgraceful contrast do they form to those principles which actuated many of the ancient philosophers, the Gentoos, the Japanese, and the worshippers of Odin? When they committed suicide, they committed it from principle, from a belief of its lawfulness, and the hope of being rewarded for what they judged an honourable sacrifice. But in modern times, we are sorry to say, when it is not the effect of madness, it is the effect of vice: and when it is the effect of vice, it proves that the vicious passions are then indulged to the highest degree; for there is no crime which a man can commit that is so strong a symptom of the violence of particular passions. It is from not attending to this circumstance that it has been found so difficult to refute the arguments in favour of suicide. If the criminality of suicide be confined merely to the violent action, many apologies may be made for it; but if it be considered solely as the effect of vice, as the strongest symptom of ungoverned passion, he who undertakes its defence must undertake the defence of what all men will loudly condemn.

As suicide was deemed a crime by the most illustrious

Suicide.

¹ Moore's Enquiry into the subject of Suicide. Lond. 1790, 2 vols. 4to.

Suidas. and virtuous of the Greek and Roman philosophers, it was considered as a crime by the laws, and treated with ignominy. By the law of Thebes suicides were to have no honours paid to their memory. The Athenian law ordained the hand which committed the deed to be cut off, and burnt apart from the rest of the body. The body was not buried with the usual solemnities, but was ignominiously thrown into some pit. In Cea and Massilia (the ancient *Marseille*), it was considered as a crime against the state; and it was therefore necessary for those who wished to destroy themselves to obtain permission from the magistrates. Plutarch acquaints us, that an unaccountable passion for suicide seized the Milesian virgins; from indulging which they could not be prevented by the tears and entreaties of parents and friends: but what persuasion and entreaty could not effect was accomplished by very different means. A decree was issued, "that the body of every young woman who hanged herself should be dragged naked through the streets by the same rope with which she had committed the deed." This wise edict put a complete stop to the extraordinary phrensy, and suicide was no longer committed by the virgins of Miletus.

In the early part of the Roman history there seems to have been seldom occasion for framing any laws against suicide. The only instance recorded occurs in the reign of Tarquinius Priscus. The soldiers who were appointed to make drains and common sewers, thinking themselves disgraced by such servile offices, put themselves to death in great numbers. The king ordered the bodies of all the self-murderers to be exposed on crosses, and this put an effectual stop to the practice. It is doubtful whether there was any standing law against suicide during the existence of the republic; but during the reign of the emperors it was thought proper to lay it under certain regulations, though not absolutely to condemn it as a crime. In Justinian's Pandects there is a law, by which it was enacted, "that if persons accused, or who had been found guilty, of any crime, should make away with themselves, their effects should be confiscated." But this punishment only took place when confiscation of goods happened to be the penalty appointed by the law for the crime of which the self-murderer was accused or found guilty, and was not inflicted for suicide committed in any other circumstances.

When the Christian church had extended its jurisdiction in the Roman empire, it was decreed in the sixth century, that no commemoration should be made in the eucharist for such as destroyed themselves; neither should their bodies be carried out to burial with psalms, nor have the usual service said over them. This ecclesiastical law continued till the reformation, when it was admitted into the statute law of England. As an additional punishment, however, confiscation of land and goods seems to have been adopted from the Danes, as we learn from Bracton.¹ At present the punishment consists in confiscating all the personal property of a *felo de se* for the use of the crown, and in excluding his body from interment in consecrated ground.

SUIDAS, a Greek lexicographer, is supposed by Fabricius to have lived during the latter part of the eleventh century; but other writers are disposed to believe that he must have belonged to a more recent period. His country and his personal history are alike unknown. From authors of various denominations he compiled an ample dictionary, which, with all its imperfections, has been found a most valuable repository of ancient erudition; and no scholar, intimately acquainted with the Greek language and literature, is unacquainted with the Lexicon of Suidas. The first edition, which is very elegantly printed, was published by Demetrius Chalcondylus, Mediol. 1499, fol. He had access

to several manuscripts. The text of Aldus has some appearance of being derived from a different source, Venet. 1514, fol. A third edition, with various interpolations, followed after a longer interval, Basil. 1544, fol. It was succeeded by the Latin version of Wolfius, Basil. 1564, fol. Basil. 1581, fol. An edition of the Greek text, accompanied with a Latin version, was published by Æmilius Portus, Colon. Allobrog. 1619, 2 tom. fol. A splendid and valuable edition was at length produced by Küster, Cantab. 1705, 3 tom. fol. Here the version of Portus has received innumerable corrections; and from the collation of manuscripts, as well as by the aid of his own critical sagacity, he effected a great reformation of the text. He was a man of superior talents, and of profound erudition; but it is admitted that he ought to have devoted a greater portion of time to so formidable an undertaking. His edition was assailed by J. Gronovius in three different publications; and to this virulent critic Küster replied in a *Diatrise Anti-Gronoviana*, of which a second edition was printed at Amsterdam, 1712, 8vo. The text of Suidas was afterwards illustrated by many other writers, nor must we fail to mention the elaborate work of Toup, *Emendationes in Suidam*, Lond. 1760-6, 3 tom. 8vo. Oxon. 1790, 4 tom. 8vo. The labours of these learned men prepared the way for a most valuable edition, recently published under the following title: "Suidæ Lexicon post Ludolphum Kusterum ad codices manuscriptos recensuit Thomas Gaisford, S.T.P. Ædis Christi Decanus, necnon Græcæ Linguae Professor Regius." Oxon. 1834, 3 tom. fol. The third volume is very thin, and merely includes three Indices. By his edition of Suidas, Dr Gaisford has made a great accession to his former reputation in a department of learning in which he has no living rival in Great Britain.

SUIT, in *Law*, the same with action. The Romans, at an early period, introduced set forms for actions into their law, after the example of the Greeks; and made it a rule, that each injury should be redressed by its proper remedy only. "Actiones (say the Pandects) compositæ sunt, quibus inter se homines disceptarent, quas actiones ne populus prout vellet institueret, certas solemnesque esse voluerunt." The forms of these actions were originally preserved in the books of the pontifical college, as choice and inestimable secrets, till one Cneius Flavius, the secretary of Appius Claudius, stole a copy and published them to the people. The concealment was ridiculous: but the establishment of some standard was undoubtedly necessary to fix the true state of a question of right, lest, in a long and arbitrary proceeding, it might be shifted continually, and be at length no longer discernible; or, as Cicero expresses it, "sunt jura, sunt formulæ, de omnibus rebus constitutæ, ne quis aut in genere injuriæ, aut in ratione actionis, errare possit. Expressæ enim sunt ex uniuscujusque damno, dolore, incommodo, calamitate, injuria, publicæ a pretore formulæ, ad quas privata lis accommodatur." And in the same manner Bracton, speaking of the original writs upon which English actions are founded, declares them to be fixed and immutable, unless by authority of parliament. And all the modern legislators of Europe have found it expedient, from the same reasons, to fall into the same or a similar method.

SUKANA, or **SUKNA**, a village of the Syrian desert, near which is a warm sulphureous spring, 140 miles south-south-east of Aleppo.

SUK EL HARF, a town of Yemen, in Arabia, twenty-eight miles south-south-east of Saade.

SUKI, a town of Anatolia, in Asiatic Turkey, governed by an aga. It is twelve miles north-north-east of Milet.

SULIAGO, or **SURIAGO**, a chain of small islands in the Pacific Ocean, extending about ninety miles in length by

Suit
||
Suliago.

¹ Bracton de Legibus et Consuetudinibus Angliæ, lib. iii. tract. 11.

Sully
||
Sultan-
hissar.

twelve in breadth. Long. 125. 27. to 128. 30. E. Lat. 9. 24. to 10. 32. N. The largest, from which the others derive their name, is twenty miles in circumference, and is twenty miles north-north-east from the coast of Mindanao. Long. 126. 27. E. Lat. 9. 27. N. There is a town of the same name on the north coast of the island of Mindanao. Long. 125. 31. E. Lat. 9. 45. N.

SULLY, MAXIMILIEN DE BETHUNE, Duke of, was born at Rosny on the 13th of December 1560, and died at Villebon on the 22d of December 1640. His name is so conspicuous in the public annals of France, that a mere outline of his personal history would require an ample allotment of space. He participated in the fortunes of Henry IV. and rendered him the most important services in the cabinet as well as the field. He was grand master of the artillery, and superintendent of the finances. Rigidly attentive to the interest of the king, he had no disposition to neglect his own; and in the course of a long life he accumulated an immense fortune, of which he laid the foundation by his marriage with Anne de Courtenay, a rich heiress. He was remarkable for his decision of character and bluntness of manners; and in spite of all the allurements presented to him, he steadily adhered to the protestant faith. The Memoirs of Sully furnish some of the most curious and valuable materials for the history of that eventful era.

SULPHUR ISLAND, an island in the North Pacific Ocean, discovered by Captain Gore in 1779, about five miles long. Long. 141. 12. E. Lat. 24. 48. N.

SULPICIA, a Roman poetess, who lived under the reign of Domitian, and has been so much admired as to be termed the Roman Sappho. We have nothing, however, left of her writings but a satire, or rather the fragment of one, against Domitian, who published a decree for the banishment of philosophers from Rome. This satire is to be found in Scaliger's *Appendix Virgiliana*, and in other collections. It was separately published, with elaborate annotations by C. G. Schwartz. Altorf. 1721, 8vo. Hamb. 1819, 4to. She is mentioned by Martial and Sidonius Apollinaris; and is said to have addressed a poem on conjugal love to her husband Calenus, a Roman knight.

SULPITIUS SEVERUS, an ecclesiastical writer, was born in Aquitania about the year 363. His father was a man of superior rank. Having received a suitable education, the son applied himself to the practice of the law, and distinguished himself by his learning and eloquence. He married a rich wife, and was thus placed in a state of greater independence. He chiefly resided at Toulouse, and at *Eluso* or *Elusio*, near Carcassonne. The death of his beloved wife weaned his affections from the world, and he is supposed to have devoted himself to an ecclesiastical, if not a monastic life. He had recourse to the instructions of Martin bishop of Tours, whose life he has written; and he likewise contracted a friendship with Paulinus bishop of Nola. The invasion of the Vandals impelled him to seek a place of refuge at Marseille, where he entered a monastery, and is supposed to have died about the year 410. His principal work is his *Historia Sacra*, deduced from the creation of the world to his own time, and written in a style superior to the standard of that declining age of Latinity. The first edition was published by Flacius Illyricus. Basil. [1556] 8vo. Various editions of his works subsequently appeared; some of which were illustrated by the notes of Sigonius, Vorstius, Horn, and Le Clerc. A more elaborate edition was undertaken by De Prato, Veronæ, 1741-54, 2 tom. 4to. He promised a third volume, which however did not make its appearance.

SULTAN, or SOLDAN, a title or appellation given to the emperor of the Turks.

SULTANHISSAR, a village of Anatolia, in Asiatic Turkey, situated near the remains of the ancient Greek city of Tralles, and twenty-three miles east of Scalanova. On

the top of an adjacent hill are found traces of some ancient buildings, particularly a temple and a theatre, with fifty rows of seats. Some remains of a magnificent portico are also seen, with two rows of pillars.

SULTANPORE, a town of Hindustan, province of Lahore, belonging to the Sikhs. Long. 74. 45. E. Lat. 31. 18. N. 2. A town in the province of Oude, pleasantly situated on the eastern bank of the Goompty river, seventy-eight miles south-east from Lucknow. Long. 82. 3. E. Lat. 26. 18. N. 3. A town in the Afghan territories, province of Mooltan, twenty miles east from the city of Mooltan. Long. 71. 40. E. Lat. 30. 38. N. 4. A town in the Mahratta territories, province of Khandesh, on the north side of the Tuptee river, ninety miles east by north from Surat. Long. 74. 22. E. Lat. 21. 35. N.

SULZER, JOHN GEORGE, a philosophical writer of distinction, was born at Winterthur, in the canton of Zürich, on the 16th of October 1720. He was the youngest of twenty-five children. At the age of sixteen, when he went to the university of Zürich, he had not the smallest notion of the sciences or of elegant literature, and consequently no taste for study. The first incident that developed a hidden germ of philosophical genius, was his meeting with Wolf's *Metaphysics*. This was the birth of his taste for science; but he wanted a guide. The clergyman with whom he lodged was an ignorant man; and the academical prelections were, as yet, above the reach of his comprehension. On the other hand, a sedentary life was not suitable to his taste; and a sociable turn of mind often led him into company, where he lost much time in frivolous amusements, yet without corrupting his morals. Who, that observed him at this period, says Mr Formey in his *Eloge*, would have thought that Sulzer would one day be numbered among the most knowing and wise men of his time? John Gessner, who became an eminent naturalist, was the instrument of Providence that rendered Sulzer's inclination to study triumphant over his passion for amusement and company. Animated by the counsels and example of this fellow-student, he applied himself to philosophy and mathematics with great ardour, and resumed the pursuit of Greek literature and the oriental languages. He was settled as a pastor in a rural district. In 1741 he published *Moral Contemplations on the Works of Nature*; and in the following year an *Account of a Journey through the Alps*, which showed at the same time his knowledge of natural history, and the taste and sensibility with which he surveyed the beauties of nature, and the grandeur and goodness of its Author. He afterwards became private tutor to a young gentleman at Magdeburg. This procured him the acquaintance of Euler, Maupertuis, and Sack, which opened to his merit the path of preferment, and advanced him successively to the place of mathematical professor in the Gymnasium of Berlin in 1747, and to that of member of the Royal Academy in 1750. In this last quality he distinguished himself in a very eminent manner, enriched the class of speculative philosophy with a great number of excellent memoirs, and was justly considered as one of the first-rate metaphysicians in Germany. But his genius was not confined to this branch of science. His universal *Theory of the Fine Arts* is a valuable production. A profound knowledge of the arts and sciences, and a perfect acquaintance with true taste, are eminently displayed in this work, and will secure to its author a permanent and distinguished rank in the republic of letters. The first volume of this excellent work was published in 1771, and the second in 1774. His *Remarks on the Philosophical Essays of Hume* is a work of real merit, which does justice to the acuteness, while it often detects the sophistry, of the Scottish philosopher. The moral character of Sulzer was amiable and virtuous: sociability and beneficence were its characteristic lines; and his virtues were animated by that sacred philosophy which

Sultanpore
||
Sulzer.

Sumatra. forms the Christian, ennobles man, and is the only source of that heart-felt serenity and sedate fortitude which support humanity, when every other object of confidence fails. He died at Berlin on the 27th of February 1779.

SUMATRA, a large island in the Eastern Seas, the most western of that great chain of islands which extends in the eastern ocean from the coasts of New Holland and New Guinea to the coast of China on the east, and westward to the Malayan peninsula. The equator divides it into two parts almost equal. It may be estimated at 1050 miles in length by 165 miles in average breadth, and its general direction is north-west and south-east: the one extremity is in 5° 56' N. and the other in 5° 56' S. This island lies exposed on the south-west to the great Indian Ocean; the north point stretches into the Bay of Bengal, to the north-east it is divided from the peninsula of Malaya by the Straits of Malacca, to the east by the Straits of Banca from the island of that name, to the south-east by the commencement of the Chinese Seas, and on the south it is separated from the island of Java by the Straits of Sunda. The origin of the name is unknown. In the east it is generally known by the name of Pulo Purichu and Indalas. It is one of the largest islands in the world, and is broadest at its southern extremity, narrowing gradually towards the north. It is of a very unequal surface. A chain of mountains runs through its whole extent: the ranges are from 3000 to 5000 feet high, and in some places much higher, being in many parts double and treble; and they run nearer to the western than the eastern shore, being seldom more than twenty miles from the sea. These mountains, though high, do not rise above the level of perpetual snow. Mount Ophir, situated immediately under the equinoctial line, is 13,800 feet above the level of the sea. Between these ridges of mountains are extensive plains, considerably elevated above the surface of the maritime lands, where the air is cool, and they are esteemed in consequence the most eligible portion of the country; and being cleared from woods, which in all other parts cover both the hills and valleys in Sumatra with an eternal shade, they are the best inhabited parts of the country. The most satisfactory account of the country is derived from the journeys into the interior by Sir Stamford Raffles, who was appointed governor of the British settlements at Sumatra, and arrived in Bencoolen in 1818; and who made excursions inland and along the coast, and also crossed the island from Bencoolen to Palembang. He afterwards proceeded from Padang, on the south coast, and, traversing the first range of mountains, penetrated to the ulterior plains; and he describes the country as populous, well cultivated, and fertile. The hills which he passed rose to the height of 5200 feet, as estimated by the barometer, and the slopes were covered with plantations of coffee, indigo, maize, sugar-cane, and all the oil-giving plants, and the lower plains were almost exclusively occupied with rice. The rice-fields are managed in the same manner as those of Java, and were equal in fertility. After arriving at the summit of the steep ascent, he observes, "our view opened on one of the finest countries we ever beheld;" "as we descended," he continues, "the scene improved; we found ourselves in an immense amphitheatre, surrounded by mountains 10,000 and 12,000 feet high; the soil on which we stood rich beyond description, and vegetation luxuriant and brilliant in every direction; the people superior to those on the coast, in general about six feet high, and proportionably stout, with clear and clean skins, and an open ingenuous countenance. They seemed to have abundance of every thing; rice, the staple food of the country, being five times as cheap as at Bencoolen, and every other article of produce in proportion. The children were deco-

rated with a profusion of silver ornaments, and particularly with strings of dollars and other coins hanging round their neck, to the value sometimes of 100 dollars. A fine breed of cattle," he continues, "which seems peculiar, abounds here, and throughout the Menangcabow country; oxen seem to be used in agriculture in preference to buffaloes; they are generally about three feet four inches high, beautifully made, and mostly of a light-brown colour, with black eyes and lashes, and are sold at from three to four dollars a head."¹ Here are also found many large and beautiful lakes, which extend at intervals through the interior of the country, and tend to facilitate the intercourse between its different districts. But little is known respecting the interior of this large and fertile island, or the dimensions, direction, and situation of the lakes. The most remarkable is one of great extent in the Batta country. There is a second in the country of Menangcabow, which is used by the inhabitants for transporting goods to and from Palembang; there is another in the Corinchia country; one in the Lam-poon country, extending to Passumah, which is very large, and in which there are boats of a large size, which carry sails, and require a day and a night to cross it. This lake is stated by Mr Anderson, who visited the east coast of Sumatra in 1822, under the orders of the East India Company, to be very large, the shore not being visible from the opposite side. The borders of the lake are reported to be in a high state of cultivation, containing numerous villages, and a dense population. The lake has an island in the centre, where edible bird-nests, so highly prized as a luxury in China, are procured. Those who navigate this lake are mostly pirates, who plunder each other, and carry off their children, selling them for slaves.² The lake of Sincara, in one of the interior valleys of the island, is described by Sir Stamford Raffles as a beautiful sheet of water, about fourteen miles long by seven broad, surrounded by mountains and hills, except on one side, where it is bounded by a plain of its own width. On the margin of this lake for two or three miles are rice-fields, plantations, and villages, rising successively above each other, and advancing up the hill nearly to the summit of the first ridge, where the forest has been cleared, and cultivation extended. On the banks of this lake are situated seven principal towns, with their numerous villages and hamlets; which being shaded by trees, form so many groves, the dark foliage of which pleasingly contrasts with the bright tints of the rice-plantations in the middle of which they are placed. At each of these towns a weekly market is held, to which the traders from the other towns and adjacent countries repair by water. There are numerous canals, and each town has one or two large boats capable of carrying six tons with one hundred men. Sir Stamford sounded at a short distance from the shore, and found bottom at 68 fathoms; but in the centre no bottom was found at 180 fathoms. The lake abounds in fish.

From the direction of the mountains, which, as has been mentioned, approach near to the western coast, being only twenty miles from the sea, while on the eastern side there is an intervening country not less than 150 miles in breadth, all the largest rivers are found on that coast. The rivers on the western coast are numerous, but they are in general too small and rapid for the purpose of navigation. And it is the vicinity of the mountains on this side that occasions the profusion of springs, as well as their rapidity and diminutive size. They have not space to accumulate in so limited a range; while the extended declivity of the eastern coast not only presents a larger surface for the formation of rivers, by the reception of rain, and by the union of subsidiary

¹ Memoir of the Life and Public Services of Sir Thomas Stamford Raffles, p. 349.

² Mission to the East Coast of Sumatra, by J. Anderson, Esq., p. 252.

Sumatra. streams, but gives them a more steady and uniform current, than where the torrent rolls immediately from the mountains. Those rivers on the eastern shore are the Siak, Indragiri, Jambi, and Palembang. They convey a large body of water into the ocean. They labour however under this inconvenience, that, owing to the continual action of the heavy surf from the great Indian Ocean, which is more powerful than the ordinary force of the stream, a bank of sand is thrown up at their mouths, which diverts their course to a direction parallel with the shore, till the accumulated waters at length force their way wherever there is least resistance. In the dry season, which is that of the southerly monsoon, the parallel course of the rivers is of the greatest extent; but during the rainy season, being in flood, they, by the greater force of their current, break through all obstructions, and recover their natural channel. The rivers on the western shores are Kataun, Indrapura, Tabuyong, and Sinkel, which, though not so large as those on the eastern shore, are still considerable streams.

Climate. The diversified surface of Sumatra gives rise to a considerable variety of climate; but it is remarkable, that on the sea-level near the shore the heats are more moderate than in other countries within the tropics. At the most sultry hour in the afternoon the thermometer fluctuates between 82 and 85 degrees: Marsden, whose work contains the fullest information concerning this island, mentions that he never saw it higher than 86 in the shade, and at sun-rise it is usually as low as 70. Inland, as the country ascends, the heat decreases rapidly, so that beyond the first range of hills the inhabitants find it expedient to light fires in the morning, and to continue them till the day advances. Frost, snow, and hail are unknown to the inhabitants in any quarter. The hill-country is liable to a fog, which is dense to a surprising degree; it is observed to rise every morning among the distant hills; the extremities of it when near at hand are perfectly defined; and it is seldom observed to disperse till about three hours after sun-set. The island is subject to the monsoons. Southward of the equinoctial, the south-east monsoon, or dry season, begins about May, and abates in September; the north-west monsoon begins about November, and the hard rains cease about March. For one half of the year the island is deluged with almost constant rains. Besides the monsoons, which vary every six months, there is a daily variation in the winds, which blow from the sea to the land during so many hours of each day, and during the night in the opposite direction, from the land to the sea, excepting only when the monsoon rages with remarkable violence; and even, says Marsden, "at such times the wind rarely fails to incline a few points, in compliance with the subordinate cause, which has not power, in these circumstances, to produce an entire change." On the west coast of Sumatra, the period of the setting in of the sea-breeze is about ten in the morning, after an hour or two of calm; and it continues till near six in the evening. The commencement of the land-breeze is about seven in the evening, when it prevails during the night, and dies away about eight in the morning. The land-wind in Sumatra is cold, chilly, and damp; an exposure to it is consequently dangerous to health, and sleeping in it is almost certain death. Thunder and lightning prevail in Sumatra in all their terrific grandeur, especially during the north-west monsoon, when the explosions are extremely violent: the forked lightning is seen in all directions, and the sky seems on fire, while the ground appears to tremble. The island is unfortunately subject to earthquakes, which often prove most destructive. Sir Stamford Raffles mentions, that a day previous to his

arrival, a violent earthquake had occurred, which had nearly destroyed every building in the place. The shocks were experienced at intervals for several weeks. But the most violent of them happened on the 18th March 1818, during the night, and was truly awful. Every building in the town of Bencoolen suffered more or less; some were laid in ruins, and others so shattered that it was found scarcely worth while to repair them. The house which was occupied by Sir Stamford he describes as being rent from top to bottom, the cornices broken, and every thing unhinged. These earthquakes are said to occur every five or six years. An earthquake occurred in 1797, which continued for three minutes with vibratory shocks. At Padang the houses were almost entirely destroyed; about 300 lives were lost; some were crushed under the ruins of falling houses, some were swallowed up by the earth opening and closing over them, and others were drowned by the sudden irruption of the waters of the ocean.¹

The soil has been celebrated for its fertility; but, according to Marsden,² it is rather sterile than rich. It is generally a stiff, reddish clay, covered with a stratum or layer of black mould, of no considerable depth, and burned to the state of a brick where it is exposed to the influence of the sun. From this there springs a strong and perpetual verdure of rank grass, brushwood, or timber trees, according as the country has remained for a longer or shorter period uncultivated; and this forest or jungle, as there is but a scanty population, affords abundant cover for wild beasts of the most ferocious kind, by which the country is infested. "There is nothing," says Sir S. Raffles, "more striking than the grandeur of the vegetation; the magnitude of the flowers, creepers, and trees, contrast strikingly with the stunted, and I had almost said pigmy, vegetation in England. Compared with the forest-trees of these tropical regions, your largest oak is a mere dwarf. Here we have creepers and vines entwining larger trees, and hanging suspended for more than 100 feet, in girth not less than a man's body, and many much thicker; the trees seldom under 100, and generally approaching 160 to 200 feet in height. One tree that we measured was, in circumference, nine yards, and this is nothing to one I measured in Java."³ The most important article of cultivation is rice, of which there are many different species, which may be ranged under two kinds, namely, the upland rice, which grows on the high and dry grounds, and the lowland or marshy rice, which grows in the low and marshy grounds. The cocoa-nut tree may also be esteemed an important object of cultivation; it serves as an article of food, and is in universal consumption, being an ingredient in most of the dishes, and the oil being employed as an article for anointing the hair, and for burning in lamps. There are also large plantations of the betel-nut tree and the bamboo. The latter, growing thick into an impenetrable mass, is used in the fortification of villages. The sago tree also flourishes, and there is a great variety of palms. The sugar-cane is cultivated, but such is the indolence or ignorance of the inhabitants, that all the sugar which they require is imported from Java; all the use they make of the sugar-cane is to chew it. Maize, Chili pepper, turmeric, ginger, coriander and cummin seed, are raised in the gardens of the natives. Pepper is an important article of cultivation. The plant appears to flourish in any of the different soils that are found in this island, and it is a great article of commerce. The pepper plants, which are in even rows, running parallel and at right angles with each other, present a fine contrast to the wild scenes of nature which surround them. The camphire tree, which grows in the northern parts of the island, is valued for its juice,

¹ Memoir of the Life and Public Services of Sir Stamford Raffles, p. 294.

² Marsden's History of Sumatra, p. 68.

³ Memoir of the Life and Public Services of Sir Stamford Raffles, p. 317.

Sumatra. which is an article of trade, and sells at a high price. The benzoin is produced from a tree which grows in the northern parts of the island. Cassia and cotton are also produced, and form articles of export. Various other shrubs and plants are cultivated, and are converted by the natives to many useful purposes. Hemp is extensively cultivated, not however for the useful purpose of making ropes, but to procure an intoxicating liquor called *bang*, which they smoke in pipes along with tobacco. Plantations of the latter plant are met with in almost every district; and there is a variety of other creeping plants, which are manufactured into twine, thread, and other articles of the same nature.

Fruits, shrubs, &c. No country in the world is more distinguished than Sumatra for the variety of fine fruits with which it abounds, and which are the spontaneous produce of the earth; for the natives bestow no more care on this than on any other production. The most remarkable are the mangustin, which is produced in abundance, and which for delicacy and flavour holds pre-eminence over all the Indian fruits; the pineapple, which, though not indigenous, grows in great plenty with ordinary culture; the orange, which is in great perfection and variety; the shaddock of the West Indies, which is here very fine, and is distinguished into the white and the red. Limes and lemons abound; as also the bread-fruit; the jack-fruit; the mango, a rich high-flavoured fruit of the plum kind; the papaw, a fruit substantial and wholesome, like a smooth sort of melon, but not very highly flavoured; the pomegranate, the tamarind, nuts and almonds of different kinds, besides various other fruits of which the names are scarcely known in Europe. Owing to the equable temperature that prevails throughout the year, there is a perpetual succession of shrubs and flowers, which diffuse a pleasant fragrance, and are many of them used in medicine, or in affording useful dyes. The castor-oil plant is found in abundance, especially near the seashore; also the caoutchouc or Indian rubber plant; the indigo plant; a red wood called ubar, resembling logwood in its properties; and the uphas, or poison-tree, whose deleterious qualities have been so much exaggerated.

Animals. The zoology of Sumatra is distinguished by some of the most remarkable animals in nature. The shelter afforded by its vast forests or tracts of jungle is most favourable to the breed of wild animals, which abound throughout the island. Numerous herds of elephants range over the forests, and are pursued and killed for their teeth; they are extremely destructive to the plantations of the natives, which they trample down by merely walking through the grounds, and thus obliterating all traces of cultivation. The rhinoceros, both the single and the double horned, is also a native of the woods. Of the ferocious animals, the tiger is the most remarkable. Here he grows to an enormous size, and his strength is so prodigious that he is enabled to drag into the woods the largest prey, and by a stroke of the fore-paw will break the leg of a horse or buffalo. Whole villages are sometimes depopulated by these animals, and great numbers of inhabitants lose their lives. Sir Stamford Raffles, who fixed his residence in the interior, east of Bencoolen, among the hills, states, among its conveniences, that the temperature was six degrees lower than on the coast; and that the only inconvenience he could suffer would be from tigers and elephants abounding in the vicinity. One of the villagers mentioned to him, that both his father and grandfather had been carried off by these animals; and he adds, that there is scarcely a family that has not lost some of its members by them, and that on the banks of one of the rivers upwards of a hundred persons had been carried off by tigers the year before; yet the inhabitants are so superstitious that they will not use any means for their extirpation. When a tiger enters a village, these ignorant people prepare rice and fruits as an offering to the animal, conceiving that he will be pleased with these

hospitable attentions, and pass on without doing them any harm. They are occasionally caught in traps, which are ingeniously contrived in the form of a cage with falling doors, into which the beast is enticed, and is then enclosed; or a large beam of timber is so placed as to fall on his back and crush him. Another expedient is to entice him to ascend a plank, which being nearly balanced, is weighed down by him when he is past the centre, and he falls upon sharp stakes prepared below. The natives sometimes contrive to poison tigers. The bear is common: he is small and black, and climbs the cocoa-trees, feeding upon the tender part or cabbage. The deer abounds in every variety of species; and the monkey tribes are innumerable. Here are also sloths, squirrels, teleggos or stinkards, civet-cats, tiger-cats, porcupines, hedgehogs, armadillos, bats of all kinds, alligators in the rivers, which are also haunted by the hippopotamus, guanos, cameleons, flying lizards, tortoises, and turtle. The alligators are very voracious, frequently destroying the people as they bathe in the river, according to their invariable custom, from which no dangers deter them. The house-lizards are four inches in length, and are the largest reptiles that can walk in an inverted position. Among the animals which are domesticated is the buffalo, which, however, exists in a wild state, and is a remarkably strong and active animal, keeping pace with the swiftest horse; and is even said by Marsden to fight an equal battle with the tiger, the females and weaker sort only being his sure prey. This animal supplies the inhabitants with milk, butter, and beef. The cow is a stranger to the country, and does not appear to be naturalized. The breed of horses is small, but they are well made and hardy. The sheep are also a small breed; the other animals are the goat and the hog, both domestic and wild; the otter, the cat, the rat, and the dog.

Frogs, toads, and reptiles of every kind, abound in the swamps; and the noise which they make on the approach of rain is tremendous. They fall a prey to the snakes, which are common in this island, and are of all sizes, some thirty feet in length, though Marsden states, that the largest he ever saw was only twelve feet long, which was killed in a hen-house, where it was devouring the poultry. He also mentions his opinion, that the bite of very few of these serpents is mortal, as he never saw a well-authenticated instance of a person suffering from them. Among the poisonous serpents is the viper; and the hooded snake is sometimes found in the country. The boa constrictor is the largest, and sometimes grows to the length of thirty feet, and is of proportionate bulk and strength.

The surrounding seas abound in fish. Among these are the duyong, a large sea-animal of the mammalia order, with two strong pectoral fins serving for the purpose of feet; the grampus-whale, a fish which derives its name from the peculiarity of its dorsal fin resembling a sail. There are, besides, sharks, skates, the *muræna gymnotus*, rock cod, pomfret, mullet, the flying fish, and many others.

Of birds there is a much greater variety than of other animals; and so numerous are the curious species, that Marsden cannot even give a list of them. They consist of peacocks, eagles, vultures, kites, and crows, jackdaws, kingfishers; the rhinoceros bird, remarkable for its horn; the stork, the snipe, coot, plover, pigeons, quails, starlings, swallows, minas, parrots and paroquets, geese, ducks, teal, &c. The Sumatran pheasant is a bird of great magnificence and beauty; the plumage being perhaps the most rich, without any degree of gaudiness, of all the feathered race.

The island may be said literally to swarm with insects, which are extremely annoying and destructive. These consist of cochroaches, crickets, bees, flies of all sorts, mosquitoes, scorpions, centipedes, and water and land leeches. These leeches are extremely annoying to those who travel in the woods; and Sir Stamford Raffles mentions, that in

Sumatra. his journeys through the woods they got into the boots and shoes of the travellers, which were filled with blood. Ants exist in immense numbers and varieties. The white ant, well known for its mischievous properties for destroying papers, furniture, &c. is found in great numbers; also the great red ant, about three fourths of an inch long, which bites severely, and usually, like the bee, leaves its sting in the wound. There are also the common red ant, the minute red ant, the large black ant, which is equal in size to the large red ant; the fire-fly, which is larger than the common fire-fly, and emits so vivid a light that words may be read by it.

Minerals.

Sumatra abounds in minerals. Gold is chiefly found in the mountainous districts in the interior of the island. No gold has been found, at least very frequently, to the southward of Limon, a branch of the Jambee river, or to the northward of Nalaboo, whence Acheen is principally supplied. Menangcabow has always been famed since the earliest periods of history for the riches of its gold mines, its iron ores, and its mineral productions in general; on which account it was that the Dutch were induced to establish their head factory in its neighbourhood. Its jurisdiction in ancient times extended over the whole of Sumatra; and it is situated about eighty miles inland from Padang, and nearly in the centre of the island. The Malays are attracted to all the districts where gold is found. They are the only persons who collect it, or dig for it; the original inhabitants confining their attention to the raising of provisions, with which they supply the Malays who search for the metal. It is found in earth taken up from the beds of rivers, and washed till the pure grains are separated and cleansed from the particles of mud and stone. The gold is found in a pure metallic state; and they simply beat or wash it, and sell it in the lumps or dust in which they find it. Some pieces have been found pure that weigh six or seven ounces; and they are sometimes joined with an equal bulk of marble, which does not detract from their value, being sold as mineralogical specimens. In some of the specimens the gold may be said rather to enclose the rock, than the latter to contain the gold. No accurate account can be obtained of the quantity of gold exported. From the west coast Marsden estimates that 10,000 ounces may be annually exported. But he has no data to calculate the exports from the eastern coast. It has been conjectured that the whole may amount to 15,000 ounces. It was sold at the settlements for L.3.5s. per ounce, but afterwards rose to L.3.18s., which would yield no profit on its exportation to Europe. The gold-dust is cleansed from impurities by a very dexterous process. A skilful person called a Pundi is employed, who by the sharpness of his eye can distinguish the dross from the ore with surprising nicety. He spreads out the dust on a kind of wooden platter; and the bare particles are touched and put aside with a piece of linen cloth rolled up to a point. There are no silver mines; but there are copper mines, of which the ore is very rich, and which resembles the Japan copper in the appearance which it presents of a mixture of gold. In the country of Menangcabow, which is nearly in the centre of the island, iron ore is collected, smelted, and formed into metal. The colour of the soil indicates its existence in many parts of the island, especially on the sea-coast, where the sand is of a strong shining black, and is attracted by loadstone. The steel which is here manufactured is of a peculiar temper, and has a degree of hardness that has never been imitated in Europe. There is, however, no industry in the island to profit by these products, and the consumption of the natives is chiefly supplied by English and Swedish bar-iron. Tin is one of the great mineral products of the island. It chiefly abounds in the neighbourhood of Palembang, on the east coast; but in many other parts its existence is indicated, and particularly in the neighbourhood of Bencoolen. Sulphur is ga-

thered in any quantity near the volcanoes, which abound in the island; yellow arsenic is also found, and is an article of traffic; and saltpetre is procured chiefly in extensive caves, the haunt of certain species of birds, of whose dung the soil is formed. Coal exists in various parts, and is washed down to the coast in floods: it is not esteemed good, being found near the surface of the earth. The veins are observed to run, not exactly in a horizontal direction, but to dip downwards; and till the pits have a certain depth no good coal is to be found. Mineral and hot springs are discovered in many districts, the waters resembling those of Harrowgate, and being nauseous to the palate. In the caves where the saltpetre is formed are found the edible bird-nests which are so highly prized in China as a luxury of the table, and to that country they are exported as an article of traffic. Some of the company's servants advanced into one of these caves 740 feet, when his lights were extinguished by the damp vapour; and into another 600 feet, through a narrow passage three feet wide and five feet high, which led into a spacious place forty feet high. Bees' wax is a commodity of great importance in all the eastern islands, and is exported to China, Bengal, and other parts of the continent, though no trouble is taken with the bees, which are left to settle where they list, and are never collected in hives. The honey is of a poor quality. Gum-lac, which, though found adhering to the branches of trees, is known to be the work of insects, as wax is of the bee, is procured in small quantities from the country near Bencoolen, and at Padang is a considerable article of trade. It is chiefly valuable for the animal part, which is soluble in water, and yields a fine purple dye. Ivory is an article of export; and elephants also are sent to the Coromandel coast, vessels being built expressly for their transport. The following are the general articles of import, as enumerated by Marsden in his comprehensive account of this island. From the coast of Coromandel, salt, blue and white cloths, chintz, and a variety of other cotton goods; from Bengal, opium and tafetas; from China, coarse porcelain, tobacco, and a number of miscellaneous commodities; from the eastern islands, a striped cotton manufacture, guns, krises, and other weapons, salt and rice; from Europe, silver, iron, lead, cutlery and other hard ware, brass wire, and scarlet cloth.

The Sumatrans are a rude people, and have made no great progress in manufacturing industry, yet there are some particular manufactures in which they excel. Many of those who have visited this country entertain an opinion that in former times it was the seat of a great Malay empire, of which Menangcabow was the capital, where arts and industry flourished; and the monuments that have been discovered by Sir Stamford Raffles afford evidence of a higher state of refinement than at present prevails. In the histories of former times, it is mentioned that great foundries of cannon were established at Acheen; and that manufactories of fire-arms and knives were carried on at Menangcabow. If this were the case, the arts have degenerated since that period, as there are now no manufactories of iron, except of nails, and various kinds of tools, such as adzes, axes, hoes, &c. They are equally ignorant of the art of the carpenter; they do not even know how to use a saw, excepting where they have been instructed by the British, by whom this instrument has been introduced. They fell trees by means of a hatchet; and when they wish to split the wood into stems, they must choose those kinds of wood of which the direction of the grain admits of its being easily split asunder. They have woods of certain qualities, which, by the help of wedges, they are enabled to split into boards. Their chief cement is made of buffalo milk, which in a hot and damp climate proves a much stronger cement than glue. They make ink by mixing lamp-black with the white of an egg. They are however very curious and ingenious in carving, both in wood and ivory, though they show no taste

Sumatra. in their designs, which are grotesque and out of nature. The handles of their knives are the chief subjects of this art; and these are in general curiously ornamented with the head and beak of a bird, or with the folded arms of a human being. In the interior, according to the observation of Sir Stamford Raffles, manufactures are more advanced. Menangcabow has always been famed for the manufacture of its kris blades. In its vicinity iron has been worked from time immemorial; and an extensive manufactory of coarse pottery, near the banks of the lake, supplies not only Padang, but Bencoolen, with that useful article. The Sumatrans are entire strangers to the art of painting and drawing. In cane and basket work they are particularly neat and expert, as well as in mats; of which some kinds are much prized for their extreme fineness, and for the beauty and taste of the borders with which they are ornamented. They excel also in the manufacture of silk and cotton cloths of varied colours, chiefly for domestic use. These are worn in all parts of the country by the natives, and especially by the women. Some of their work is very fine, and the patterns prettily fancied. Their apparatus for weaving is, however, of the rudest description, and renders their progress tedious. The women are expert at embroidery, the gold and silver thread for which is procured from China, as well as their needles. Gunpowder is manufactured in various parts of the island, chiefly among the people of Menangcabow, the Battas, and Achenese, among whom, as they are frequently at war, it is an article in great request. It is not, however, well made, being imperfectly granulated, and often hastily prepared for immediate use. Different kinds of earthenware are manufactured in the island. The manufacture of filagree is here carried to the greatest perfection. There is no manufacture in any part of the world that has been more justly admired and celebrated than the fine gold and silver filagree of Sumatra; but this is not the work of the Sumatran artisan; it is a manufacture of the Malays, the original and ancient inhabitants, to whose superior taste and industry many of the monuments of art which remain are ascribed. This manufacture is in universal use in the country; and its fineness and beauty form a singular contrast to the coarseness of the tools which are employed in the workmanship, and which are rudely and inartificially formed by the goldsmith from any old iron that he can pick up. A piece of iron hoop as a wire-drawing instrument, an old hammer-head stuck in a block as an anvil, and two old nails tied together as a pair of compasses, are the chief instruments. They have no bellows, but blow the fire with their mouths through a reed. They are very inexpert at polishing the plain parts, but in other respects nothing can exceed the extraordinary delicacy of the Malay work. They are extremely expert in manufacturing fishing-nets, and springes for catching birds.¹

Sciences. The proficiency of the Sumatrans in science is very limited. Their numeration table does not extend beyond tens of thousands. Their utmost attainment in arithmetic is to multiply and divide several places of figures. Of geography they have no idea whatever. They know not that the country they inhabit is an island, nor have they any general name for it. Habit renders them expert in travelling through woods, where they perform journeys of weeks or months without seeing a dwelling. In the pathless woods they make marks on the trees for the future guidance of themselves and others. They have no notion of astronomy; and the Malays, as well as the Arabs and other Mahomedans, fix the length of the year at 354 days, or twelve lunar months of twenty-nine and a half days. They mark the time of the day by the position of the sun in the heavens; which is sufficiently exact for all practical purposes so near

the equator, where the sun ascends and descends almost perpendicularly, and rises and sets at all seasons of the year within a few minutes of six o'clock. They are entirely destitute of either history or chronology, the memory of all past events being only preserved by tradition. Their literary compositions, says Sir Stamford Raffles, seldom go farther back than the introduction of Mahomedanism, except to give some romantic tale, from which little or nothing can be gathered. But he adds, "it was my good fortune to discover in Java the vestiges of a former high state of literature and the arts, in poems, in the ruins of temples, in sculptured images, in ancient inscriptions." This active and philosophical inquirer into the ancient state of these eastern countries discovered also monuments in Sumatra, inscribed with characters which corroborated all his views concerning their ancient civilization. The people are fond of music, and have many instruments, which are mostly borrowed from the Chinese and other eastern nations. Their musical instruments are chiefly of the noisy kind; and they have no science, though they have a few simple tunes. In Sumatra the art of medicine is at an equally low ebb with the sciences. It consists in the application of a few simples, and chiefly in certain charms. Every old man or woman is a physician; and they are rewarded in proportion to their success, though they generally contrive to procure payment in advance for the charms which they dispose of to their patients. They either administer juices inwardly, or they apply outwardly the juices of certain trees, or, chopping their leaves small, they apply them as poultices. They have no knowledge of anatomy, nor do they practise phlebotomy. The inhabitants are assailed with leprosy under various forms. It is sometimes a disease of the skin; but there is another form of the disease, under which the flesh mortifies and falls off the bones; and the disorder being deemed infectious, the patient is driven into the woods, where victuals are left for him from time to time by his relatives. The small-pox makes terrible ravages in the island, and the inhabitants have a great dread of this loathsome and fatal disease. Among the other great benefits, the enlightened Sir Stamford Raffles introduced among them the vaccine inoculation, which they expressed the utmost willingness to receive. Insanity they imagine to be a possession by the evil spirit; and their mode of exorcism is to enclose the unfortunate victim in a hut, to which they set fire about his ears, suffering him to make his escape through the flames in the best manner he can. This, along with other barbarous practices, marks the little progress which they have made in knowledge or moral improvement.

The Malay language, which is understood to be the original language in the peninsula of Malacca, has extended itself through all these Asiatic islands, and has become the common tongue in this part of the globe, being spoken everywhere along the coasts of Sumatra. It also prevails in the inland country of Menangcabow, and is understood in almost every part of the island. From the smoothness and sweetness of its sound, it has been called the Italian of the east. Their writing is in the Arabic character, very little corrupted; owing to which, and the adoption of the Mahomedan religion, a great number of Arabic words are incorporated with the Malay. Various other languages are spoken in Sumatra besides the Malay, which all, however, bear a manifest affinity to each other, and spring from the same root; and this common language is spread over all the islands in the Eastern Seas, more or less corrupted in different places, but still retaining the same stock of radical words. Marsden has remarked, that in the most distant places, "as the Philippines and Madagascar, the deviation of the words is scarcely more than is observed in

¹ Marsden's Sumatra, p. 41, &c.

Sumatra. the dialects of neighbouring provinces in the same kingdom.¹

Political divisions.

Government, manners, character.

It is conjectured that in former times Sumatra was the seat of an extensive Malay empire, and of arts and commerce. All traces of this empire are now obliterated, and it is only from the monuments of ancient architecture that such historical inferences are drawn. The modern divisions of the island are chiefly the empire of Menangkabow and the Malays, the Achenese, the Battas, the Rejangs, and the people of Lampong. The government among them seems chiefly aristocratical. It is the rule of chief men, and in some parts the despotic assumption of power by some aspiring chief. Their government, however, seems to be founded in opinion; their submission is voluntary. Almost all the governments throughout the island partake of the patriarchal and the feudal. Where the people by conquest have been compelled to submit to a foreign yoke, feudal manners are followed; where, on the other hand, the natives have been long undisturbed by revolutions, the patriarchal sway prevails. The Malay and the native Sumatran differ in mind fully as much as in features and person. The Malay inhabitants have an appearance of degeneracy from those ancient virtues which laid the foundation of an extensive empire. Their portrait, as drawn by various travellers, has many dark traits. Marsden describes them as proud, yet without that pride which restrains them from meanness and fraud. They can practise low cunning and the most plausible duplicity, dissembling under an outward calmness the strongest passions and most inveterate antipathy, until the moment of gratification is found. Veracity, gratitude, and integrity, are not among their qualities. They seem to make no distinction between honour and infamy; and their courage is the result of some momentary and vindictive impulse, which hurries them on to deeds of desperation, not that calm and steady valour which distinguishes the European in the day of battle. These harsher traits of the Malay character are greatly softened in the portrait drawn by Sir Stamford Raffles. Their piracies he traces to their warlike disposition, which, he observes, only requires to be directed into a better course; and their vindictive spirit, to high notions of honour. The attacking his enemy with the kris by the Malay is the counterpart of duelling among the European nations. He proudly defends his property, his life, and character in this manner, which is not secured to him by law; and he seldom draws his kris except in defence of his honour, or in some warlike enterprise. This practice, however reprobated, has produced a habitual good breeding among the Malays.² The original Sumatran has many of the Malay vices, and some virtues belonging to himself, which are however of the negative kind. He is mild, peaceable, and forbearing, but when roused to resentment he is implacable. He is temperate and sober, abstemious both in meat and drink. His diet consists of vegetables, and water is his only beverage; yet his hospitality is extreme, and bounded only by his ability. The Sumatrans are continent in respect to women, modest and courteous in their behaviour, grave in deportment, seldom excited to laughter, and habitually patient. On the other hand, they are litigious, indolent, and addicted to gaming. They gamble with dice or with shells, and have various games on chequered boards and other delineations. They are addicted to cock-fighting in an extraordinary degree; and when in affluent circumstances, their propensity to it is so great that it resembles rather a serious occupation. Quarrels, attended with dreadful consequences, have often arisen on these occasions.

Laws, customs.

The Sumatrans have no written code of laws and their

various disputes are settled by custom and precedent. There is no class of persons invested with legislative powers. The chiefs of districts judge in cases both civil and criminal. In pronouncing their decision, they do not say such is the law, but such is the custom; and their decision is generally submitted to. The want of written laws was supposed by the East India Company's servants likely to occasion endless disputes; and in the year 1779 a code was promulgated for the benefit of those under their jurisdiction. It may be greatly doubted, however, how far such a system, constructed by Europeans, would suit the wants of an uncivilized people, in preference to their own tried and well-known modes, however rude and inartificial. Legal disputes chiefly originate among them in the intricacy of marriage-contracts. Their laws of marriage are very coarse and rude; a wife being obtained by purchase, and becoming to all intents and purposes the property and slave of her husband, who may dispose of her, only making the first offer to her relations. When a man dies, his effects are equally distributed among his children; but if one possesses remarkable abilities above the rest, he receives a larger portion; a contrivance, apparently, for producing division and strife. Land is so plentiful among them, that they rarely consider it a subject of right; another proof of the low state of civilization. They have few capital punishments, and, according to Marsden, corporal punishment is rare; murder being compensated by money, and adultery being punishable by fine. But recent discoveries by Mr Marsden himself, and by Sir Stamford Raffles, as well as by others who have lately visited the island, have laid open among the Battas and other interior tribes such horrid and ferocious practices, as would not be believed unless authenticated by evidence above all dispute. The Battas are an extensive and populous nation, occupying the whole of that part of the island lying between Acheen and Menangkabow, reaching to both shores. The coast is but thinly inhabited; but the people are said to be as thick as the leaves of the forest, and to amount to between one and two millions. Their laws are remarkably severe; and for adultery, midnight robbery, for intermarrying in the same tribe, or for a treacherous attack on a house, village, or person, the criminals are condemned to be eaten alive, which shocking sentence is actually carried into execution by these savages. They also eat the prisoners taken in war. The mode of proceeding is thus described. "The victim is tied to a stake with his arms extended; the party collect in a circle around him, and the chief gives the order to commence eating. The chief enemy, when it is a prisoner, or the chief party injured in other cases, has the first selection; and after he has cut off his slice (the victim being alive), others cut off pieces according to their taste and fancy, until all the flesh is devoured. It is either eaten raw or grilled, and generally dipt in sambul, a preparation of Chili pepper and salt, which is always in readiness. Rajah Bandaharru, a Batta, and one of the chiefs of Tappanooly, asserted that he was present at a festival of this kind about eight years ago, at the village of Subluan, not nine miles distant, where the heads may be still seen. When the party is a prisoner taken in war, he is eaten immediately, and on the spot. Whether dead or alive, he is equally eaten; and it is usual even to drag the bodies from the graves, and, after disinterring them, to eat the flesh." Sir Stamford relates another example of this practice, too horrid to be detailed, at which the British resident was invited to attend; and after a great part of his flesh was eaten while he was still alive, one man approached and stabbed him to the heart; which, he adds, "was rather out of compliment to the foreign visitors, as it is by no means the custom to give the

Sumatra.

¹ Marsden's Sumatra, p. 163.

² Memoir of the Life and Services of Sir Stamford Raffles, p. 256.

*Sumatra. coup de grace.*¹ Such details present a shocking picture of the ferocious habits of these worse than savages; and few will, after this, be inclined to listen to Sir Stamford's praise, that "they are honest and honourable, and possess many more virtues." It seems an abuse of the name of virtue to couple it with such brutalities.

Till about 150 years ago, the southern coast of Sumatra was dependent on the king of Bantam, whose deputy collected the tribute of pepper, and filled up any vacancies in the magistracy, by nominating new functionaries, or confirming those already chosen. Soon after this time the English established a settlement at Bencoolen, and the deputy of the king of Bantam informed the chiefs that he should visit them no more; and raising two chief men to the supreme power, he gave into their hands the government of the country, and withdrew his master's claim. The interior of the country is ruled by princes or chiefs. Near the sea-coast it is much influenced by the Europeans, who are virtually the rulers; but the influence of the East India Company's residents never extended to any distance in the interior, which was indeed not known until it was explored in 1818 by Sir Stamford Raffles. In the districts adjacent to the coast the power of the resident was exerted for the benefit of the people. He has always been considered their protector from the injustice and oppression of their chiefs. By fraud and legal chicanery, though not by open acts of violence, they take advantage of the ignorant and necessitous, and contrive to strip them of their property, their family, and their liberty. To prevent these iniquitous practices, the perversion of justice in consequence of bribes, the subornation of witnesses, and such like practices, the resident's authority has always been useful; and when it is accidentally relaxed, oppression and disorders ensue.

The British settlement at Bencoolen has however been the scene of great disorders, arising from the mal-administration of the residents sent thither by the Company. Although it was one of the first establishments formed by the Company in the east, it had benefited less than any other part of the country under their control. The establishment formed was solely for the purpose of procuring pepper, in a country deficient in population, and in a new and unappropriated soil, which could only be rendered productive by capital and industry. The expenses of the establishment amounted to L.100,000 per annum, the returns were only a few tons of pepper. On the first formation of their settlements on the coast of Sumatra, the Company held the native chiefs bound to compel their subjects each to cultivate a certain number of pepper vines, the produce to be delivered exclusively to the Company's agents, at a price far below the value of the labour employed in the cultivation. For a certain time, while the influence of the chiefs continued, the stipulated quantity of pepper was delivered to the agents; but the oppression soon began to be heavily felt; the cultivators withheld their labour, and the chiefs, destitute of the power to force it, left to the Company's agents the cruel task of driving the people to their unprofitable toil. Prior to 1801, the establishment maintained at Fort Marlborough was considerable; and the private trade of Bencoolen, carried on by the governor and council, and the servants of the Company, was extensive, and contributed to the improvement of the settlement. The trade consisted in the importation of articles from Western India, which were principally exported to the Java market. From the restrictive policy of the Dutch government, and the corruption of its servants, a contraband trade had arisen, which was carried on, particularly that portion of it which consisted in opium and piece-goods, through the medium of Bencoolen. In 1801 the original establishment of Fort

Marlborough was reduced, and it became a dependency of Sumatra. Bengal; and a strictly economical and purer system of administration being introduced by Mr Parr, the resident, great reductions took place in all the public establishments, by which numbers of people were suddenly thrown out of employment, and many reduced to starvation. At the same time, contracts were entered into for a certain quantity of labour, to be employed in the cultivation of pepper, and the pepper plantations were farmed out to the Company's servants; and, that the resident might have an interest in forcing the people to cultivate pepper, he was allowed one dollar per cwt. on the quantity delivered to government. Along with pepper, Mr Parr endeavoured to enforce the cultivation of coffee; and a long series of measures, offensive to the natives, was also carried into effect. Insults were offered to the principal chiefs, which produced a deep feeling on men of violent and vindictive tempers; and the attempt to compel the cultivation of coffee brought matters to a crisis. A deep-laid plot was formed for vengeance; the measures of the government were fully discussed; secret oaths were administered, and the revolt soon after broke out. The government-house was surrounded, the guards were overpowered, and the resident, blind to his danger, was murdered. The measures that followed were dictated by the spirit of revenge. It was thought unsafe to touch the chiefs; but several of the people were blown from the mouths of guns. Every village within a certain distance was consigned to the flames, and the country was laid waste, as if it were intended to surround the settlement with a desert. For its protection, the fruit-trees, venerable from age, and considered as the tutelary deities of the place, and their destruction an act of sacrilege, were cut down; every thing that could afford shelter was levelled with the ground, and the inhabitants were turned loose upon the country, forbidden to appear with crises, and degraded by every stigma that jealousy could devise. Of 1000 head of cattle possessed by one village, only 300 remained in 1820, the rest being either stolen, shot, or dispersed.

In 1818, when Sir Stamford Raffles landed at Bencoolen as lieutenant-governor, he beheld nothing but dilapidation and ruin; the roads impassable, the highways overrun with rank grass, the government-house a den of ravenous dogs and polecats. As the chief revenue of the government was derived from gaming and cock-fighting farms, these immoral practices were publicly patronized by it. The consequence was, that there was no security either for person or property; murders and robberies were daily committed, and never detected; and the grossest profligacy was seen in every direction. The new governor, with that rare union of wisdom and benevolence which so eminently qualified him for a legislator, immediately commenced measures of reform. The African slaves who were employed in the hard work of the colony, and who were dissolute and depraved, and their children in a state of vice and wretchedness, were declared free before an assembly of native chiefs; the forced cultivation of pepper was abolished; the people were allowed as formerly to wear crises and other weapons, according to immemorial usage. The gaming and cock-fighting farms, so destructive of every principle of good government, social order, or morals, were abolished; and various reforms of other evils equally mischievous were carried into effect. Under the wise, beneficent, and enlightened rule of Sir Stamford Raffles, it is scarcely necessary to add, that the country, the revenue, the trade, and the morals of the people, began to improve. He was a rare example of true disinterestedness and patriotism. The object of his life was the happiness of the people under his sway; his wisdom suggested the means; and the eminent success

¹ Memoir of the Life and Services of Sir Stamford Raffles, p. 426.

Sumaun
||
Sumbhul-
pore.

of his plans, both in Sumatra and in other places, attest the judgment with which they were formed. During his short administration the cultivation of rice was extended, the spice plantations were established, the population increased, and the people were conciliated; so that this wise and beneficent ruler had good reason to boast that he was making a country and a garden out of a wilderness, and laying the foundation of the future civilization of Sumatra. We have no data for estimating the population of this island. Sir Stamford reckoned the inhabitants of the Batta country, the valley beyond the first range of mountains, to be between one and two millions. But this is merely a conjecture, and there are many districts still unexplored. The British establishment at Bencoolen was withdrawn in 1824, when Sumatra was relinquished to the Dutch. (F.)

SUMAUN, a town of Hindustan, province of Agra. It is twenty-eight miles north-north-east from the town of Etawah. Long. 79. 5. E. Lat. 27. 6. N.

SUMBAWA, a large island in the Eastern Seas, about 180 miles in length by forty in average breadth. It is situated between the eighth and ninth degrees of south latitude, and is separated from Lombok by the Straits of Allass. It is almost divided into two equal parts by a deep bay, which indents it in the middle. This island is divided into the different states of Beema, Dompoo, Tambora, Sangur, Pekat, and Sumbawa, all governed by their respective chiefs, who were formerly either allies or under the protection of the Dutch East India Company, and were all sufficiently obedient, with the exception of the chief of Sumbawa, who rebelled. Near the north-east end of the island, on a fine bay which stretches seven or eight leagues south, is situated the town of Beema, remarkable for its excellent harbour, the sides of which are bold and high, and the approach safe; but the passage through is sometimes dangerous, from the strong current which generally prevails, and the great depth of water, as 100 fathoms of line, though close in shore, will hardly reach the bottom. The channel in some places is only 150 or 200 yards across; but the depth is so great that a ship of the line may sail on either side within thirty yards of the rocky mountains. These give a grand and picturesque appearance to the channel, which terminates in a safe and commodious basin, presenting one of the finest harbours in the world. On the east side of the bay stands the town of Beema, which comprehends under its jurisdiction the Straits of Sapy, the whole of Manzeray, and the island of Gonong Api. The island produces sappan wood, rice, horses, saltpetre, sulphur, wax, birds' nests, tobacco, &c., though there is but little trade carried on at this place. The number of horses exported under the appellation of Beema horses is very considerable. There are two volcanic mountains in the island, Gonong Api and another, which are looked upon with superstitious veneration by the inhabitants. Gold-dust is found in Sumbawa, particularly in the district of Dompoo, which also supplies teak-timber. Pearls are fished for in the large bay to the westward of Beema Bay, as also at Pekat.

SUMBHULPORE, a district of Hindustan, in the province of Gundwana, situated between the twenty-first and twenty-second degrees of north latitude. It is of an unwholesome atmosphere, especially to foreigners, owing to the mountainous and woody nature of the country, to the sudden vicissitudes of heat and cold, and to the quantity of jungle which it contains. The soil in the valleys is a rich loam, which produces sugar, cotton, and all kinds of grain; and in the mountains gold and diamonds are found. This district constituted the ancient kingdom of Gurrah, and was overrun by the armies of Aurungzebe. On the decline of the Mogul empire it became independent; and in the war between the British and the Mahrattas in 1803 several of the pergunnahs or parishes were taken possession of by the former. The capital, which is of the same name, is situ-

ated on the east side of the Mahanuddy river. Long. 83. 47. E. Lat. 21. 33. N.

SUMBOONHAUT, a town and temple in the Ghoorkha country, in Nepal. It is celebrated for a temple containing from time immemorial the sacred fire, and is annually resorted to by innumerable pilgrims from Bootan and Thibet, and is a source of considerable revenue to the Nepaul government. Long. 85. 38. E. Lat. 27. 33. N.

SUMBUL, a town of Hindustan, province of Delhi, and district of Bareilly, situated on the Yaruwadur river. It is fifty-two miles west-north-west from Bareilly.

SUMISHORE, a town of Hindustan, in the province of Bahar. It is forty-six miles west-north-west from Bettiah. Long. 84. 15. E. Lat. 27. 15. N.

SUMMER, the name of one of the seasons of the year, being one of the quarters when the year is divided into four quarters, or one half when the year is divided only into two, summer and winter. In the former case, summer is the quarter during which, in northern climates, the sun is passing through the three signs Cancer, Leo, Virgo, or from the time of the greatest declination, till the sun again comes to the equinoctial, or has no declination; which is from about the 21st of June till about the 22d of September. In the latter case, summer contains the six warmer months, while the sun is on one side of the equinoctial; and winter the other six months, when the sun is on the other side.

SUMNUM, a small town of Persia, in the province of Khorassan. It is the capital of a rich district containing fifty villages, and bounded on the north by Mount Elburz, and on the south by the Great Salt Desert.

SUMY, a city of Russia, the capital of a circle of the same name, in the province Slobod-Ukraine, 911 miles from St Petersburg. It stands on the river Psiol, where the Sumy falls into it. It is surrounded with walls and ditches, contains two stone and eight wooden churches, 1230 houses, with 13,600 inhabitants, who distil much brandy, and are celebrated for the horses which they breed. Long. 28. 1. E. Lat. 50. 50. N.

SUMPTUARY LAWS (*Leges Sumptuarie*), are laws made to restrain luxury. Most ages and nations have had some such laws. Political writers have been much divided in opinion with respect to their utility. Montesquieu observes that luxury is necessary in monarchies, as in France, but ruinous to democracies, as in Holland. With regard to England, whose government is compounded of both species, it may still be a dubious question, says Blackstone, how far private luxury is a public evil, and as such cognizable by public laws.

SUN, SOL, ☉, in *Astronomy*, the great luminary which enlightens the world, and by its presence constitutes day.

SUNBURY, a town of the county of Middlesex, in the hundred of Spelthorne, eighteen miles from London. It is finely situated on the left bank of the Thames, between Hampton Court and Shepperton, and is much resorted to by the lovers of angling in the summer season. The population amounted in 1811 to 1655, in 1821 to 1777, and in 1831 to 1863.

SUNDA, STRAITS OF. The arm of the sea which separates the large islands of Sumatra and Java is so called by the Europeans, and by the Malays Sunda Kalapa. The length of this channel, taken from the flat point to Varkens or Hog Point, is about seventy miles; and on the opposite coast, from Java Head to Bantam Point, about ninety. The passage, though wide, is occasionally dangerous, from the currents. There are two passages formed by Prince's Island, which lies in the mouth of the straits; one between it and Java, which is generally made use of during the south-west monsoon, in order that they may approach as close as possible to the shore, so as to anchor to escape the danger of being driven to sea by the currents which set strongly out of the straits to the westward. The other pas-

Sumboon-
haut
||
Sunda.

Sunday
||
Sundeeep
Isle.

sage, called the Great Channel, is sometimes resorted to during the south-east monsoon; but it is navigated with the greatest difficulty, in consequence of the opposition from the south-easterly gales. In the narrowest part of the straits is an island, which, from its situation, is called Thwart the Way, or Middle Isle; on both sides of which a strong current runs during the whole year, setting with the prevailing easterly or westerly winds either to the north-east or south-west. The other chief islands in the straits are Prince's Isle, Krakatau, and Pulo Baby. The rest are small and insignificant, mostly level, founded on beds of coral, and covered with trees.

SUNDAY, or the LORD'S DAY, a solemn festival observed by Christians on the first day of every week, in memory of our Saviour's resurrection. In the Breviary and other offices, we meet with Sundays of the first and second class. Those of the first class are, Palm, Easter, Advent, and Whitsunday, those of *Quasimodo* and *Quadragesima*. Those of the second class are the common Sundays. Anciently each Sunday in the year had its particular name, which was taken from the introit of the day; which custom has only been continued to some few in lent; as *Reminiscere*, *Oculi*, *Lætare*, *Judica*. Some are of opinion that the Lord's Day mentioned in the Apocalypse is our Sunday, which they believe was so early instituted by the apostles. Be this as it may, it is certain a regard was paid to this day even in the earliest ages of the church; as appears from the first Apology of Justin Martyr, where he describes the exercise of the day as not much unlike to ours. But it was Constantine the Great who first made a law for the proper observance of Sunday; and who, according to Eusebius, appointed it should be regularly celebrated throughout the Roman empire. Before him, and even in his time, they observed the Jewish Sabbath as well as Sunday; both to satisfy the law of Moses, and to imitate the apostles, who used to meet together on the first day. By Constantine's law, promulgated in 321, it was decreed, that for the future the Sunday should be kept as a day of rest in all cities and towns; but he allowed the country people to follow their work. In 538, the council of Orleans prohibited country labour; but because there were still many Jews in Gaul, and the people fell into many superstitious uses in the celebration of the new Sabbath, like those of the Jews in that of the old, the council declares, that to hold it unlawful to travel with horses, cattle, and carriages, to prepare food, or to do any thing necessary to the cleanliness and decency of houses or persons, savours more of Judaism than of Christianity.

SUNDAY ISLAND, a small island on the east coast of New Holland, discovered by Captain Bligh in 1788. Lat. 11. 58. S.

SUNDEEP ISLE, an island of Bengal, in the district of Chittagong, about twenty miles in length by ten in breadth. It is the seat of a salt manufacture by the government, subordinate to the Bulwa and Chittagong agency. The soil is fertile and affords excellent pasture for cattle, and might be easily rendered of much more value than it is at present; but its station for the manufacture of salt supercedes every other use. Ships may safely approach it on all sides except the north. The entrance of the river is safe, and it possesses good anchorage, where ships may remain safe during the adverse monsoon; but the climate is dangerous to Europeans. The town is situated about a mile from the western shore, on the north bank of a creek called Sittal. Towards the end of the sixteenth century a number of Portuguese had settled on the coasts of Arracan and Chittagong; and, having recommended themselves by their bravery and maritime skill, had risen to considerable commands in the service of the native princes. But in consequence of their turbulent conduct, they were expelled by the rajah of Arracan from his dominions, and many of them

put to death. A remnant however joining together, elected Sebastian Gonzales for their chief, who took possession of this island, and having collected about 3000 men, extended his conquests. He was at last subdued by the rajah of Arracan, who retained possession of the island till 1666, when it was conquered by the Mogul armies, and came into the possession of the British along with the province of Bengal. Long. of the town 91. 36. E. Lat. 22. 25. N.

SUNDELLA, a town of Hindustan, in the nabob of Oude's territories. It is thirty miles north-west from Lucknow. Long. 80. 30. E. Lat. 27. 5. N.

SUNDERBUNDS, an extensive and woody district of Bengal, situated at the mouth of the eastern or great branch of the river Ganges. It is a dreary region, consisting of a labyrinth of rivers and creeks, all of salt, except those that communicate immediately with the principal arm of the Ganges, these numerous natural canals being so disposed as to form a complete inland navigation. Bishop Heber describes the prospect on the banks of the river as a dismal unbroken line of black wood and thicket, apparently impenetrable and interminable, which, he adds, "one might easily imagine to be the habitation of every thing monstrous, disgusting, and dangerous, from the tiger and the cobra de capello down to the scorpion and mosquito. The seamen," he continues, "spoke of the shore with horror, as the grave of all who were so unfortunate as to remain many days in its neighbourhood." On a nearer approach, the appearance of the Sunderbunds improved; the woods assumed a greater variety of green and shade; several round-topped trees and some low palms were seen among them, and a fresh vegetable fragrance was wafted from the shore.

In tracing the coast of this delta, eight openings are found, each of which appears to be the principal mouth of the Ganges. The navigation through the Sunderbunds is effected chiefly by means of the tides, there being two distinct passages; the one named the Southern or Sunderland Passage, and the other the Balliaghaut Passage. The first is the longer of the two, and opens into the river about sixty-five miles below Calcutta. The latter opens into a lake on the east side of Calcutta; the navigation is intricate, extending more than 200 miles through a forest, divided into numberless islands by various channels, and the prospects are romantic. At one time the masts of vessels are entangled among the branches of trees, and at other times they sail on a broadly-expanded river skirted with beautiful woods. The water is everywhere salt; and the whole tract is uninhabited except by tigers, and wild deer, their natural prey. During the dry season, the lower shores of these rivers are visited by salt-makers and woodcutters, who supply Calcutta with wood for fuel from these desolate tracts, and many of whom every year are devoured by tigers; these animals growing here to an enormous size, and so ferocious that they have been sometimes known to swim off and attack boats. In addition to these, the waters swarm with alligators. Some attempts have been made to bring parts of the Sunderbunds into cultivation, but with little success, as the want of fresh water must always prove a great obstacle to improvement; nor is it desirable to settle such an unhealthy tract while so many healthy stations remain unoccupied. The Sunderbunds are deemed of importance as a political barrier to Bengal on the south.

SUNDERLAND, a large and important seaport town on the east coast of England, in the county of Durham, 268 miles from London by way of Stockton. The municipal boundary includes the townships of Monkwearmouth, Bishopwearmouth, and Southwick, which form an area of 5095 acres. The river Wear, after running through the centre of the borough, falls into the sea. Sunderland proper is situated on the south or right side of the river, and is a

Sundella
||
Sunder-
land.

Sunder-
land.

place of considerable antiquity. At the latter end of the twelfth century it received a charter from Bishop Pudsey, which gave it equal privileges with those enjoyed by Newcastle, and from that time it has risen into importance. The town consists of one long street, under the names of Sunderland High Street and Bishopwearmouth High Street, and the two together extend to nearly a mile in length. This continued street is broad, well built, having many respectable shops, and in it are the principal buildings. With this exception, Sunderland presents the appearance of one mass of small houses, of considerable age, crowded together, with interstices of narrow streets and lanes; and here the population is extremely dense. To this crowded state of the population, together with the want of cleanliness, may be traced the fearful ravages of the cholera in 1832, which first broke out in England at this port. On the outskirts of the town there are some good streets, which are rapidly extending, with excellent houses, and in them the higher class of the inhabitants reside. There are various well frequented literary institutions in the town, to most of which libraries are attached. It contains numerous charitable institutions, which are liberally supported. The great object of interest is the magnificent iron bridge which crosses the Wear, and connects Sunderland with Monkwearmouth. It consists of a single arch of 236 feet in span, formed by small segments of iron, having a height of upwards of 100 feet from the centre of the arch to the surface of the river at low water, which enables vessels of above 300 tons burden to pass under by merely lowering their top-gallants. The projector of the bridge was Rowland Burdon, Esq. of this neighbourhood, who subscribed L.23,000 out of the L.27,000 which it cost. The harbour is constructed at the mouth of the river, by means of two piers of more than 200 yards in length, which form a beautiful promenade. It is defended by a battery, near to which are extensive brick barracks, capable of holding 2000 men. At the end of the north pier there is a lighthouse. The water in the harbour is too shallow to admit large vessels, and they are loaded and discharged by means of large boats locally called keels. Great advantages have been gained by the formation of a railway, running through the eastern part of the town, in the direction of the low quay; by which means the coals and other products of the interior are more easily and expeditiously shipped than higher up the river, where great inconvenience was frequently experienced from its crowded state above the existing staiths where the coals are kept. The trade, which is principally in the building of vessels and shipment of coals, is on the increase. Of the former, a hundred can be laid on the stocks at the same time; and when it is mentioned that there are upwards of thirty yards for building ships, five for small craft, and four dry and floating docks, besides a large basin or dock, which is constructed on the left bank, near the mouth of the river, the shipping interest of the port must appear to be of great value. In the year 1836 the number of ships which left the port was 994, with a tonnage of 153,415; and in 1837 they had increased to 1338, with a tonnage of 193,133. The coal-trade employs many vessels and hands. It is calculated that upwards of 2000 seamen belonging to the town are occupied in the trade, besides those employed in the keels. The quantity of coals shipped for home consumption in 1836 was 971,190 tons; for foreign consumption, 170,367 tons. In 1837 the quantity for home use was 931,944 tons; for foreign, 242,252 tons. In addition to those important branches of industry, there are several extensive manufactories for chain-cables, ropes, sail-cloths, salt, glass, and pottery. Lime also forms a considerable part of the trade, upwards of 40,000 tons being annually shipped. The value of the custom-duty received at this port for the year 1836, after deducting all expenses, amounted to L.71,637, and for the year 1837

L.80,072. The municipal government of the borough is vested in a mayor, fourteen aldermen, and forty-one councillors, and it is divided into seven wards. The borough returns two members to parliament. In 1821 the population of Sunderland alone amounted to 14,725, and in 1831 to 17,060. In 1821 the conjoined population amounted to 31,891, and in 1831 to 40,735.

SUNDRABORN, a small state and town on the island of Celebes.

SUNERAMPORE, a town of Bengal, district of Dacca, situated on the Megna river. Long. 91. E. Lat. 24. 5. N.

SUNGEI TENANG, a country in the interior of Sumatra, between the second and third degrees of south latitude. It is mountainous, and the access to it is extremely difficult, from high ranges of mountains, and thick forests which intervene.

SUNNINGHILL, a parish in Berkshire, in the hundred of Cookham, twenty-two miles from London, and five miles from Staines. It is finely situated in the most delightful part of Windsor forest. It chiefly consists of elegant villas, and was once much visited on account of some mineral springs, which had great reputation in removing paralytic complaints. Besides the hill, the parish contains the liberty of Early, and the townships of Sandford and Woodley. The whole population amounted in 1811 to 1534, in 1821 to 1648, and in 1831 to 1701. A small portion of this parish is on the opposite side of the Thames, and in the county of Oxford.

SUPEREROGATION, in *Theology*, what a man does beyond his duty, or more than he is commanded to do. The Romanists strenuously contend for works of supererogation, and maintain that a stock of merit is accumulated, of which the church has the disposal, and which she distributes in indulgences according to her own pleasure. This absurd doctrine was first invented towards the close of the twelfth century, and modified and embellished by St Thomas in the thirteenth. Men were then taught to believe that there actually existed an immense treasure of merit, composed of the pious deeds and virtuous actions which the saints had performed beyond what was necessary for their own salvation, and which were therefore applicable to the benefit of others; and the guardian and dispenser of this precious treasure was the Roman pontiff; and that of consequence he was empowered to assign to such as he thought proper a portion of this inexhaustible source of merit, suitable to their respective guilt, and sufficient to deliver them from the punishment due to their crimes. The reformed churches do not allow of any work of supererogation; but hold, with the apostles, that when we have done our best, we are but unprofitable servants.

SUPERFICIES, or SURFACE, in *Geometry*, the outside or exterior face of any body. This is considered as having the two dimensions of length and breadth only, but no thickness; and therefore it makes no part of the substance, or solid content, or matter, of the body. The terms, or bounds, or extremities, of a superficies, are lines; and superficies may be considered as generated by the motions of lines. Superficies are either rectilinear, curvilinear, plane, concave, or convex. A rectilinear superficies is that which is bounded by right lines; curvilinear superficies is bounded by curve lines; plane superficies is that which has no inequality in it, or risings, or sinkings, but lies evenly and straight throughout, so that a right line may wholly coincide with it in all parts and directions; convex superficies is that which is curved and rises outwards; concave superficies is curved and sinks inwards.

SUPERFLUOUS INTERVAL. See MUSIC.

SUPERINTENDENT, which is equivalent to bishop, denotes an ecclesiastical superior in several reformed churches, particularly among the Lutherans of Germany.

SUPERLATIVE, in *Grammar*, one of the degrees of

Sundra-
born
||
Superla-
tive.

Superparticular Proportion
||
Superstition.

comparison, being that inflection of adjective nouns that serves to augment and heighten their signification, and shows the quality of the thing denoted to be in the highest degree.

SUPERPARTICULAR PROPORTION, or *Ratio*, is that in which the greater term exceeds the less by unit or 1: as the ratio of 1 to 2, or 2 to 3, or 3 to 4.

SUPERPARTIENT PROPORTION, or *Ratio*, is when the greater term contains the less term once, and leaves some number greater than 1 remaining: as the ratio of 3 to 5, which is equal to that of 1 to $1\frac{2}{3}$; of 7 to 10, which is equal to that of 1 to $1\frac{3}{7}$.

SUPERSTITION, a word that has been used so indefinitely that it is difficult to determine its precise meaning. From its resemblance in sound to the Latin word *superstes*, a survivor, it is evidently derived from it, and different attempts have been made to trace their connection in signification. In the dialogue of Cicero "De Natura Deorum," Balbus says that they who prayed and sacrificed whole days that their children might survive them, were called superstitious. Lactantius censures this etymology, and avers that they were not called superstitious who wished that their children might survive them (for this we all wish), but because they who survived their parents worshipped their images. Others again affirm that superstition is derived from *superstes*, because it consisted in considering the dead as if they were alive. But these etymologies are solely conjectural, and we consider conjectures as absurd in philology as we do in science; they may mislead, but are seldom of any benefit. The usual meaning affixed to the word superstition, both in the Latin and English languages, is so different from *superstes*, that its change of meaning must be owing to some accident after which it is in vain to inquire. If we had not known that the word *paganus*, a pagan, was derived from *pagus*, a village, because the heathens in a certain period of the Christian history lived in villages, the whims and fancies of etymologists would not have thrown much light on the subject.

Without labouring, from the aid of etymology, to define superstition, which is a word of a very extensive signification, we shall consider to what objects it is applied; and then, by observing what is common to them all, we shall be enabled to fix with some degree of precision the meaning of the term. We apply it to the idolatry of the heathens; we apply it also to the Jews, who made the will of God of no effect by their traditions, and substituted ceremonies in place of the religion of their fathers. We say also that Christians are guilty of superstition; the Romanists, who believe in transubstantiation and in the efficacy of prayers to saints; and those Protestants who esteem baptism and the Lord's Supper, and the punctual performance of other ceremonies, without regard to morality, as sufficient to ensure salvation. Those persons are also reckoned superstitious who believe, without any evidence, that prophecies are still uttered by divine inspiration, and that miracles are still performed. The word is also extended to those who believe in witchcraft, magic, and apparitions, or that the divine will is declared by omens or augury; that the fortune of individuals can be affected by things indifferent, by things deemed lucky or unlucky, or that diseases can be cured by words, charms, and incantations.

Through all the particulars which we have enumerated, there runs one general idea, the belief of what is false and contrary to reason. From this, however, we must not suppose that whatever is false and contrary to reason may be denominated superstition. Superstition has always a reference to God, to religion, or to beings superior to man. We do not however distinguish all false and irrational opinions in religion by the name of superstition. We do not, for instance, apply this name to the opinions which some of the ancients entertained, that God is the soul of the world, and that men are only portions of him separated for a time; or

that the soul after death lives successively in different bodies. If we examine the subject with more attention, we shall discover that the foundation of superstition is ignorance of the moral attributes of God; for we never say a man is superstitious for entertaining erroneous opinions of the natural attributes of God. Some of the Socinians have denied the prescience of God; and a French philosopher has not only rejected the belief that he is a spirit, but has presumed to say that he is composed of a species of crystals. The first of these opinions discovers very imperfect ideas of God, and the second is the height of impiety and absurdity; yet the Socinians have not been accused of superstition, nor can this French philosopher be suspected of it. We do not call every false opinion concerning the unity or moral attributes of God by the name of superstition, as, for instance, the opinion which some sceptics have supported, that God is not good; for, as was mentioned before, superstition always involves the idea of credulity. It does not consist in falsely denying that God possesses any particular moral attributes, but in believing more than what is true concerning them; in forming mean, unworthy ideas of them; in supposing that he is guided by blind passion like mankind, and enjoins upon his creatures commandments which are irrational and absurd.

As superstition arises from ignorance and credulity in the understanding, so it has also a seat in the passions. Fear has been commonly considered as a passion of the human mind, from which it chiefly derives its origin; and there is no doubt that more superstition has arisen from fear united with ignorance and credulity, than from any other passion; yet it would certainly be improper to exclude all other passions. We cannot account for the superstition of the Egyptians, without supposing that much of it arose from gratitude. They worshipped the Nile, because it distributed fertility and abundance over the land of Egypt; and they worshipped some animals, merely because they prevented the increase of other animals which were noxious. Thus they adored the ibis, because it destroyed the eggs of the crocodile.

Having thus endeavoured to analyse the ideas comprehended under the word superstition, we may sum them up in a few words. It respects God and beings superior to man, and extends to our religious opinions, worship, and practices; and may be defined absurd opinions and actions arising from mean and defective ideas of the moral attributes of God. Let us apply this definition to the different species of superstition already mentioned.

But before entering upon this application, it may be proper to observe, that superstition involves the idea of a blameable inattention to reason, or a credulity arising from an indolence of understanding. We generally make a distinction between the imperfect opinions which a savage, from the necessary effects of his situation, forms of the attributes of God, and those which civilized nations entertain. We say the savage is ignorant, and we ascribe his ignorance to his situation; but we call the Roman Catholic superstitious, and we blame him for not having those just ideas of God which he might have obtained by opening his Bible, or by the exercise of his understanding in the favourable situation in which he is placed. Superstition, then, does not originate so much from the natural weakness of the human understanding, as from a misapplication or a neglect of it.

We cannot therefore with any propriety apply the name *superstition* to polytheism in general; for what all the ancient philosophers, after much study and reflection, concluded to be true, could never proceed from credulity and inattention, but from their situation. We speak very properly, however, when we call idolatry by the name of superstition; because there is no man so devoid of understanding as not to be capable of discovering that a piece of

Superstition.

Supersti-
tion.

metal, or wood, or stone, can neither hear nor answer petitions. Superstition was a name which the ancient philosophers gave to those who entertained mean opinions of the gods, or did foolish things to obtain their favour. According to Theophrastus, the superstitious man is one who, having washed his hands, and sprinkled himself all round, leaves the temple with a laurel leaf in his mouth, with which he walks about the whole day. Or, if a weasel should cross his path, he will not advance a step till he has thrown three stones over the road. If he find a serpent in his house, he rears a place of devotion on the spot. He often purifies his house, will not sit upon a grave, or touch a dead person. He is anxious about the interpretation of his dreams, will not offer a sacrifice unless his wife go along with him, or, if she is engaged, he takes the nurse and the little children. He purifies himself with onions; and when he sees a mad or an epileptic person, he spits in his bosom. Such was the character of superstition in the days of Theophrastus. All these whimsical ceremonies were performed in order to prevent mischief, and to avert the wrath of the gods; and therefore perfectly correspond with the definition given above.

It is only necessary to consider a little the superstitious opinions and practices among Jews and Christians, to be sensible that they have all arisen from mean and absurd ideas of the moral attributes of God; for they have generally entertained noble opinions of his natural attributes. The Jews considered God as a partial being, who had a predilection for their nation in preference to all others, and preferred external homage and ceremony to moral purity. If the Romanists think consistently, they must esteem God as a being who can be prevailed upon by the importunity of one dead man to assist another, or as a being whose patience would be fatigued with hearing prayers constantly. Hence their practice of praying to saints. They in effect believe, however they may deceive themselves, that God is unjust, or they could not believe transubstantiation; for it supposes that God can give commands directly contrary to those principles of belief with which he has endued the human mind. They consider a strict adherence to a variety of ceremonies, to forms, pomp, and show, as essential to the worship of God; and thus they evidently betray most inadequate conceptions of the creator and governor of the universe. They thought it their duty to extirpate heretics: this was supposing God a cruel and revengeful being. Even among Protestants, we are sorry to say, a great deal of superstition remains: we have not yet learned to consider God as a spirit, who is to be worshipped in spirit and in truth, as a pure, moral, benevolent being; and hence arise all the superstitious practices which prevail in some Protestant churches.

Besides those superstitious opinions and practices which entirely respect our duty to God, there are others which may be termed vulgar superstitions. These also arise from imperfect and mean ideas of the moral attributes of God. To believe vulgar prophecies, which are always the effusions of madness or knavery, is to suppose that God, who has drawn a veil over futurity, and only delivers prophecies to accomplish some great moral purpose, sometimes gives them for no purpose at all, or to gratify idle curiosity, or to disclose such a knowledge of what is to happen as is inconsistent with the free agency of man and the moral administration of the world. Nor is it less superstitious to believe in vulgar miracles. To believe in them, is to believe that God suspends the laws of nature for the most trivial purposes, or to countenance fraud and worldly ambition: it is to receive the most extraordinary facts upon the most unsatisfactory evidence. The belief of witchcraft, of apparitions, and the second sight, may be resolved into the same principle. To suppose that God would communicate the power of doing mischief, and of controlling his laws, to crea-

tures, merely for gratifying their own passions, is unworthy of God. The belief of apparitions is equally inconsistent with the goodness of God. The same objection rises against the second sight as against the belief of vulgar prophecies, and may also be extended to omens, to astrology, to things lucky and unlucky, and to fortune-telling. As to the different devices and charms for preventing and curing disorders, they resemble in every respect false miracles.

A judicious history of superstition would be a curious and entertaining work, and would exhibit the human character in a remarkable point of view. Superstition is most prevalent among men of weak and uncultivated minds; it is more frequent in the female sex than among men, and abounds more in the rude than in the refined stages of society. The general features of it have been the same in all ages; but it assumes certain peculiarities, according to the diversity of character in different nations. It gained admission into the science of medicine at an early period. He who was endowed with superior genius and knowledge was reckoned a magician. Dr Bartolo was seized by the inquisition at Rome in the seventeenth century, because he unexpectedly cured a nobleman of the gout. Diseases were imputed to fascination, and hundreds of poor wretches were dragged to the stake for being accessory to them. Mercatus, physician to Philip II. of Spain, a writer of uncommon accuracy and information, appears strongly inclined to deny the existence of fascinator diseases; but he is constrained to acknowledge them for two reasons; 1st, because the inquisition had decided in favour of their reality; 2dly, because he had seen a very beautiful woman break a steel-mirror to pieces, and blast some trees by a single glance of her eyes.

As the opinions concerning the cause of diseases were superstitious, those concerning the method of curing them were not less so. In the *Odyssey* we read of a cure performed by a song. Josephus relates, that he saw a certain Jew, named Eleazar, draw the devil out of an old woman's nostrils by the application of Solomon's seal to her nose, in presence of the Emperor Vespasian. Many different kinds of applications were used for expelling the devil. Flagellation sometimes succeeded admirably; purgatives and antispasmodics were other modes of discharging him. Dr Mynsight cured several bewitched persons with a plaster of assafoetida. How the assafoetida was so efficacious, was much disputed. Some thought the devil might consider so vile an application as an insult, and run off in a passion; but others very sagely observed, that as devils are supposed to have eyes and ears, they might likewise have noses.

Nor was it only in medicine that these superstitious opinions were entertained, they also prevailed in natural philosophy. The pernicious effects in mines, which we now know are occasioned by noxious air, were confidently imputed to the demons of the mine. Even Van Helmont, Bodin, Strozza, and Luther, attributed thunder and meteors to the devil. Chemists were employed for centuries in search of the philosopher's stone, with which they were to perform miracles. It was a common question among philosophers in the seventeenth century, whether the imagination could move external objects; a question generally decided in the affirmative.

Though superstition be generally the mark of a weak mind, such is the infirmity of human nature, that we find many instances of it among men of the most sublime genius and most enlightened minds. Socrates believed that he was guided by a demon. Lord Bacon believed in witchcraft; and relates that he was cured of warts by rubbing them with a piece of lard with the skin on, and then nailing it with the fat towards the sun on the post of a chamber window facing the sun. Henry IV., one of the most illustrious of monarchs, was very uneasy before his assassination, on account of some prophecies. Sully declares,

Supersti-
tion.

Supine
||
Supper.

that one of the considerations that kept him faithful to his master in the most unpromising state of his affairs, was a prediction of La Brosse, that Henry would make his fortune. The astrologer Morin directed Cardinal de Richelieu's motions in some of his journeys. The enlightened Cudworth defended prophecies in general, and called those who opposed the belief of witchcraft by the name of atheists; and the predictions of Rice Evans were supported in the eighteenth century by the celebrated names of Warburton and Jortin. Dr Hoffmann, the father of the modern theory and practice of medicine, in a dissertation published in the large edition of his works in 1747, says, that the devil can raise storms, produce insects, and act upon the animal spirits and imagination; and, in fine, that he is an excellent optician and natural philosopher, on account of his long experience. Dr Johnson is supposed to have believed in the second sight.

With respect to the effects of superstition on the human mind, they are indeed deplorable. It chains down the understanding, and sinks it into the most abject and sordid state, and keeps it under the dominion of fear, and sometimes of cruelty. Where once it takes possession, it has a tendency to become extreme, and generally becomes so intolerable, that men of reflection and learning conspire its destruction. The Christian religion gave a violent shock to the heathen superstition; the reformation in a great measure demolished the superstition of the church of Rome; and the superstition which remained among Protestants after their separation from that church has been gradually yielding to the influence of enlightened reason, or to the bold and daring attacks of infidelity and deism. We behold the prospect of its ruins with pleasure, and thank the deists for their zeal; but it is from the firm hope that the religion of Jesus will arise in all its beauty and simple majesty, and be admired and respected as it deserves; for, mean and contemptible as superstition certainly is, we would rather see men do what they reckon their duty from superstitious principles, than see anarchy and vice prevail, even though attended with all the knowledge and liberality of sentiment which deism and infidelity can inspire.

SUPINE, in Latin grammar, part of the conjugation of a verb, being a verbal substantive of the singular number and the fourth declension. There are two kinds of supines; one, called the *first supine*, ending in *um* of the accusative case, which is always of an active signification, and follows a verb of motion, as *abiit deambulatum*; the other, called the *last supine*, and ending in *u* of the ablative case, is of a passive signification, and is governed by substantives or adjectives, as *facile dictu*.

SUPPER, the evening repast. Suppers that are heavy should be avoided, because the stomach is more oppressed with the same quantity of food in a horizontal posture than in an erect one, and because digestion proceeds more slowly when we sleep than when we are awake. They should be eaten long enough before bed-time, that they may be nearly digested before going to sleep, and then a draught of pure water will dilute that which remains in the stomach.

Definition.

SUPPER of the Lord, otherwise called the *Eucharist*, is a sacrament ordained by Christ in his church, of which the outward part is bread and wine, and the inward part or thing signified the body and blood of Christ, which the majority of Christians believe to be in some sense or other taken and received by the faithful communicants.

Controversies about the outward and visible sign.

There is no ordinance of the gospel which has been the subject of more violent controversies between different churches, and even between different divines of the same church, than this sacrament; and though all confess that one purpose of its institution was to be a bond of love and union among Christians, it has, by the perverseness of man-

kind, been too often converted into an occasion of hatred. The outward and visible sign, and the inward and spiritual grace, have equally afforded matter of disputation to angry controversialists. Many members of the church of Rome condemn the Greek church and the Protestants for using leavened bread in the Lord's Supper, contrary to the example set them by our Saviour; while the Greek church in general, and some Protestant societies in particular, unite with the church of Rome in censuring all churches which mix not the wine with water, as deviating improperly from primitive practice.

That it was unleavened bread which our Lord blessed and brake and gave to his disciples as his body, cannot be questioned; for at the time of the passover, when this ordinance was instituted, there was no leavened bread to be found in Jerusalem.¹ For the mixed cup, the evidence is not so decisive. It is indeed true, that the primitive Christians used wine diluted with water; and if we may believe Maimonides,² it was the general custom of the Jews, as well at the passover as at their ordinary meals, to add a little water to their wine, on account of its great strength; but that this was always done, or that it was done by our Saviour in particular, there is no clear evidence. Origen indeed affirms,³ that our Lord administered wine unmixed; and he was not a man to hazard such an affirmation, had there been in his days any certain tradition, or so much as a general opinion, to the contrary. On this account we have often heard with wonder the necessity of the mixed cup insisted on by those who without hesitation make use of leavened bread; for if it be essential to the sacrament that the very same elements be employed by us that were employed by our Saviour, the necessity of unleavened bread is certainly equal to that of wine diluted with water.

But the mixed cup is said to be emblematical of the blood and water which flowed from the side of our Lord when pierced by the spear of the Roman soldier, while the absence of leaven is emblematical of no particular circumstance in his passion. This argument for the mixture is as old as the era of St Cyprian, and has since been frequently urged with triumph by those who surely perceived not its weakness. The flowing of the blood and water from our Saviour's side was the consequence either of the spear's having pierced the *pericardium*, or more probably of an *ascites* or *hydrothorax*, occasioned by his cruel and lingering death. But whatever was the cause of it, how can the mixing of wine with water in the sacrament be emblematical of the flowing of blood and water separately? Such a mixture surely bears a more striking resemblance to the reunion of the *serum* and *crassamentum*, after they had been separated, by whatever cause. We urge not these objections to the mixed cup from any dislike that we have to the practice. It is unquestionably harmless and primitive; and we wish that greater regard were paid to primitive practices than the generality of Christians seem to think they can claim: but let the advocates for antiquity be consistent; let them either restore, together with the mixed cup, the use of unleavened bread, or acknowledge that neither the one nor the other is essential to the sacrament. This last acknowledgement must indeed be made, if they would not involve themselves in difficulties from which they cannot be extricated. If either the mixed cup or unleavened bread be absolutely necessary to the validity of the sacrament, why not wine made from the grapes of Judæa? why not that particular kind of wine which was used by our Saviour? and where is that wine to be found?

But the controversies respecting the outward part or sign of the Lord's Supper are of little importance when compared with those which have been agitated respecting the inward part or thing signified; and of these we hasten to give

Supper.

Frivolous.

About the thing signified.

¹ Exod. xii. 15, 19.

² In Mishnam.

³ Hom. xii. in Hieremiam.

Supper. as comprehensive a view as the limits prescribed to such articles will admit.

Our blessed Lord, in the same night that he was betrayed, "took bread, and blessed it, and brake it, and gave it to the disciples, and said, Take, eat; this is my body. And he took the cup, and gave thanks, and gave it to them, saying, Drink ye all of it; for this is my blood of the new testament, which is shed for many for the remission of sins." Such was the institution of the Lord's Supper as it is recorded in the gospel by St Matthew; and we have the same account of it, in almost the very same words, by other three inspired writers, St Paul, St Mark, and St Luke. That it was the bread which Christ blessed and brake that is here called his body, and the wine over which he gave thanks that he styles his blood of the new testament, will admit of no reasonable doubt; but in what sense they became so, has been the subject of many controversies.

Doctrine of
the church
of Rome.

The church of Rome, which holds, that after consecration, Jesus Christ, God and man, is really, truly, and substantially, contained under the outward appearances of the bread and wine, informs us, that about the middle of the mass, when the priest, taking into his hand, first the bread and then the wine, pronounces over each separately the sacred words of consecration, the substance of these elements is immediately changed by the almighty power of God into the body and blood of Christ; but that all the outward appearances of the bread and wine, and all their sensible qualities, remain. This more than miraculous change is called transubstantiation, and is founded on the philosophy of Aristotle, which resolves all bodies into *matter* and *form*; for it is only the *matter* or imperceptible substance which supports the *forms* or sensible qualities of bread and wine, that is changed into the *substance* or matter of the body and blood of Christ; so that this divine matter, coming into the place of the former earthly matter, supports the same identical *forms* which it supported. Hence we are told, "that Jesus Christ, now present instead of the bread and wine, exhibits himself to us under those very same outward *forms* or appearances which the bread and wine had before the change." Could this doctrine be true, it would be abundantly mysterious; but, to add to the mystery, we are further informed, that under each kind is contained Jesus Christ whole and entire, his body and blood, his soul and divinity; so that when a man eats what has the appearance of a wafer, he really and truly eats the body and blood, the soul and divinity, of Jesus Christ; and when he afterwards drinks what has the appearance of wine, he drinks the very same body and blood, soul and divinity, which not a minute perhaps before he had wholly and entirely eaten! The ingenious author from whose work we have taken this account of the Romish doctrine concerning the real presence, may perhaps reject our inference, that the orthodox members of his church must believe the *soul* and *divinity* of Christ to be *eaten* and *drunk* in the Lord's Supper; but he cannot deny that, according to his statement of the Romish faith, the soul and divinity are both received whole and entire into the stomach of each communicant. He says, indeed, that "communion consists in receiving Jesus Christ whole and entire, his sacred body, his precious blood, his blessed soul, and his adorable divinity, into our *souls*;" but that which was formerly bread and wine unquestionably goes into the *stomachs* of the communicants; and since, according to him, it is now the body and blood of Christ, the soul and divinity must go thither with it, for these four cannot be separated. This our author himself grants. "The Scripture," says he, "positively declares, that Christ rising

again from the dead, dieth no more; death shall no more have dominion over him (Rom. vi. 9). Consequently his body, his blood, and his soul, shall never more be separated from one another; and as the union of his divine and human natures can never more be broken, so neither can these, his two natures, united in his divine person, be ever separated. From this it necessarily follows, that wherever the body of Christ is, there also his blood, his soul, and his divinity, must of necessity be in like manner."

Now, whether we suppose, with this author, that the soul and divinity of Christ directly carry his body and blood with them into the human soul, or, trusting in some degree to the evidence of sense, believe that the body and blood carry his soul and divinity with them directly into the stomach of each communicant; is it credible, is it possible, that the high and lofty One, who inhabiteth eternity, and whom the oracles of truth assure us that even the heaven of heavens cannot contain, should be *substantially* received *whole* and *entire* into a finite spirit like the human soul, or into a body so limited as the human stomach? Our author says it is; declaring that, "by the blessed *presence* of Jesus Christ, *whole and entire within us*, are communicated to our souls all the heavenly graces which are the effects of the holy communion: such as the sanctification of the soul by an increase of justifying grace; the rendering of it more pure, more holy, more beautiful, more agreeable, in the eyes of God; the cleansing of the soul from all those venial sins and imperfections of which we repent, and preserving us from falling into mortal sins; the uniting of us in a most intimate manner with Jesus Christ, who comes to us in this holy sacrament on purpose to dwell in our souls and abide with us; and the giving us a pledge and earnest of a glorious immortality, to the enjoyment of which it brings us at last, if we persevere to the end in the grace of God."

The consequence of the doctrine of transubstantiation is the *sacrifice of the mass*, by which, it is said, God's acceptance of Christ's sacrifice on the cross is obtained for the actual benefit of those persons in particular for whom the mass is offered. In the work so often quoted, we are told that "Jesus Christ our redeemer, who is both our high priest and our victim, who, in order to perfect the work of our redemption, and reconcile man with his offended Creator, offered himself once in a bloody manner upon the cross, in order to communicate and apply to the souls of individuals those graces which, by his death, he merited for mankind in general, continues to offer himself daily upon the altar in an unbloody manner, by the ministry of his priests, in the *mass*. The sacrifice of the cross and that of the mass are both one and the same sacrifice, because in both the victim is the same and the high priest the same, viz. Jesus Christ. The only difference is in the *manner* of offering. On the cross he offered himself in a bloody manner, and actually died; whereas on the altar he is offered up to God in an unbloody manner, not *actually* dead, but under the *appearance* of death;" so that the communicants not only eat the man Jesus Christ, but even eat him alive!¹

It is known to all our readers that this doctrine of transubstantiation was one cause of the breach between the church of Rome and those various societies which call themselves reformed churches. The real and substantial change of the bread and wine into the body and blood of our Lord is rejected by every reformer, as a change contradictory and impossible, and fraught with the most impious consequences; and volumes have been written to expose the weakness of those arguments which have so often been vainly urged in its support. It has been shown to imply

¹ This whole account of the Romish doctrine respecting the sacrament of the Lord's Supper is taken from a work in two small volumes, called "The sincere Christian instructed in the Faith of Christ, from the written Word." Its author is a man of learning, and great personal worth; and as he fills a high station in the church of Rome, we cannot doubt but that he has given a fair view of the doctrine of that church respecting this and every other article of which he treats.

Supper.

Supper. numberless absurdities, such as, that the same thing can be in a million of different places, *whole* and *entire*, at the same instant of time; that it is above 1800 years old, and yet may be not more than one minute; that *forms* or sensible qualities are real things, independent of their subject and the sentient beings who perceive them; that the infinite and eternal God, who created and sustains the universe, is himself wholly and substantially comprehended by the human soul; and that the half, or fourth, or tenth part of the body of Christ, is equal to the whole of that body. That these are necessary consequences of transubstantiation, has been so completely proved in various works to which every reader may have access, that it is needless for us to repeat arguments so hackneyed; but there are two objections to that doctrine, which, as we do not remember to have met with them elsewhere, and as they appear to us absolutely conclusive, it may be worth while to state in this place.

Implies
numberless
contradictions,

is contrary
to Scrip-
ture.

and inca-
pable of
proof.

The advocates for the real presence in the Lord's Supper contend, that every word relating to that ordinance is to be taken in the strictest and most literal sense; and they affect to triumph over the Protestants, because their notions of the sacrament cannot be supported without having recourse to figure and metaphor. This however is a very vain triumph; for we hesitate not to affirm, that supposing transubstantiation possible, and even capable of proof, there is not in the whole New Testament a single word or a single phrase which, if interpreted *literally*, gives the slightest countenance to that wonderful doctrine. The reader will remember that transubstantiation, as we have stated it from a dignitary of the Romish church, and as it is in fact stated by the council of Trent, consists in a change of the matter, imperceptible substance, or *substratum*, of the bread and wine, into the matter, imperceptible substance, or *substratum*, of Christ's body and blood; for all parties agree that the sensible qualities of the bread and wine remain, and, according to the Romanist, are, after the consecration, either supported by the *matter* of Christ's body and blood, or hung upon nothing. But the phrase τοῦτό ἐστι τὸ σῶμά μου, if taken in the literal sense, cannot possibly denote the consequence of such a change as this; for every person at all acquainted with the Greek language, especially the language of the Peripatetic school, knows that τὸ σῶμά μου signifies, not the *matter* or *substratum* of my body divested of its sensible qualities, but the body of me in its natural state, consisting of matter and qualities, or matter and form united. Unless therefore the *sensible qualities*, as well as the *matter* of the bread and wine, give place to the sensible *qualities* as well as the *matter* of our Saviour's body and blood, and unless he appear glorified on the altar as he appeared on the mount at his transfiguration, the words τὸ σῶμά μου must be interpreted figuratively. Had the apostles understood their Master's words in the sense in which they are understood by the church of Rome, they would have rendered them into Greek, not τοῦτό ἐστι τὸ σῶμά μου, "this is my *body*," but τοῦτό ἐστι ἡ ὕλη τοῦ σώματος μου, "this is the *matter* of my body." In like manner, when St John relates¹ that Jesus said, "Whoso eateth my flesh and drinketh my blood, hath eternal life, and I will raise him up at the last day," had he understood his adorable Master to speak of his flesh and blood in the Eucharist in the sense in which they are taught to be there by the church of Rome, he would have represented him as saying, not Ὁ τρώγων μου τὴν σάρκα, καὶ πίνων μου τὸ αἷμα, but Ὁ τρώγων τὴν ὕλην τῆς σαρκὸς μου, καὶ πίνων τὴν ὕλην τοῦ αἵματος μου, "whoso eateth the *matter* of my flesh, and drinketh the *matter* of my blood, hath eternal life, and I will raise him up at the last day."

But further, supposing this singular conversion possible in itself, it cannot be rendered credible, however stated in any language that ever was or ever will be spoken by man.

At first sight it may appear paradoxical to affirm that a possible fact cannot be so related as to obtain credit; but that transubstantiation, if possible, is such a fact, will be apparent on the slightest consideration.

The relation which subsists between things and words is arbitrary; so that what is termed *body* in English, is *σῶμα* in Greek, and *corpus* in Latin; and the same thing might with equal propriety (had the authors of these languages so pleased) have been expressed in the first by *soul*, in the second by *νοῦς*, and in the third by *anima*. The consequences of this are, that there is no universal language spoken, that the natives of one country understand not the speech of those of another, and that different men speaking the same language are perpetually liable to mistake each other's meaning. Between the *substrata* of bodies and their *sensible qualities* there is a relation founded in nature, so that the sensible qualities which indicate the substance to which they belong, to be *gold*, for instance, in one country, indicate the same thing in every other country, and have done so from the beginning of time. The sensible appearances of bodies therefore are a universal language, the language of the Author of Nature, by which he declares to his creature man, that though the ὕλη πρώτη, or primary matter of all bodies, may be the same kind of substance, yet the ὕλη προσεχῆς of one body, or the internal combination of its primary parts, differs from that of another; that gold, for instance, has a different *substratum* or *basis* from iron, lead, or silver; that the internal organization or structure of the body of an ox is different from that of a horse; and that the *internal substance* or *substratum* which exhibits the appearances of bread and wine is different from that which supports the sensible qualities of flesh and blood. Supposing therefore the doctrine of transubstantiation to be possible and even true, it would still be impossible, by any statement in human language, or by any argument urged in its support, to render that doctrine an object of rational belief; for if it be said that the words τοῦτό ἐστι τὸ σῶμα μου were spoken by a divine person, who could neither be deceived himself nor intend to deceive us, it may be replied, that the sensible appearances of bread and wine, which are confessed to remain, are likewise the language of a divine person, even of the Creator and Governor of heaven and earth; that this language addressed to the sight, the taste, the touch, and the smell, is equally intelligible to all nations; that since the creation of the world its meaning has never been mistaken by the scholar or the clown, the sage or the savage, except in this single instance of our Lord's flesh and blood exhibiting the sensible appearances of bread and wine; and that it is therefore infinitely more probable that the members of the church of Rome should mistake the meaning of the words τοῦτό ἐστι τὸ σῶμά μου, which, though spoken by Christ, are part of the language of men, and liable to all its ambiguities, than that all mankind should mistake the language of God himself, which is liable to no ambiguities, and which was never in any other instance misunderstood by a single individual. Should transubstantiation therefore be really true, its truth can never be proved or rendered probable, but by an immediate operation of the Spirit of God on the mind of man; and he who is conscious of no such operation on his own mind, may rest assured that the Father of mercies, who knows whereof he is made, will never bring upon him, for his incredulity in this instance, any of the anathemas denounced by the church of Rome upon those who place implicit confidence in the universal language of Him who created them, in opposition to her figurative and contradictory interpretations of the written word. Of the transubstantiation of the elements a visible miracle would afford no proof. Had the water been changed into wine at the

Supper.

¹ Chap. vi. 54.

Supper. marriage in Cana of Galilee for the express purpose of bearing testimony to this singular conversion, what must have been the consequence on the minds of those who witnessed that miracle? Nothing, we think, but scepticism or distrust of their own faculties; for they would have had the very same evidence that *no* substantial change was wrought on the elements, as that the water was *actually* turned into wine.

Doctrine of the Lutherans incredible.

Though the reformed churches unanimously reject the doctrine of transubstantiation, and of course the sacrifice of the mass, its inseparable consequence, they are far from being agreed among themselves respecting the nature of the Lord's Supper; and the notions of this ordinance entertained by some of them appear to us as untenable as any part of the doctrine of the church of Rome. The Lutherans believe that the body and blood of Christ are really and substantially present with the bread and wine; that the body is really and truly eaten, and the blood really and truly drunk, by the communicants; and that whatever motion or action the bread has, the body has the same.¹ According to them, therefore, the same sensible appearances are exhibited by two substances united in some inexplicable manner, which is neither a personal union, nor incorporation, nor the enclosure of the body within the bread; nor does it last longer than while the sacrament is celebrating. This union is generally called *consubstantiation*; but they reject the term, contenting themselves with asserting the real presence, without presuming to define the mode by which the body and blood of Christ are united to the sacramental elements.

It would be superfluous to waste time in replying to this doctrine. Every reader sees that it implies the possibility of the same thing's being whole and entire in a million of places at one and the same instant of time, which has been so often urged as an unanswerable objection to the Romish doctrine; and it is fraught with this additional absurdity peculiar to itself, that two bodily substances may at once occupy the same place, which is directly contrary to our notions of solidity. It may likewise be observed, that whatever be the real sense of our Saviour's words, he says expressly, "This is my body;" this thing which I give you, and which you see and feel: whereas, had he meant what Luther and his followers teach, he would surely have said, "*With* this bread receive my body, *with* this cup receive my blood."

Of the early Calvinists,

The notions of some of the early Calvinists respecting the Lord's Supper are very mysterious, and expressed in language of which we are not sure that we understand the meaning. In the year 1561 an attempt was made in France to bring the Catholics and Protestants to an uniformity of doctrine on this great topic of controversy; and deputies were appointed by both parties to meet at Poissy, and debate the question in a friendly manner. The principal managers on the side of the Catholics were the cardinals of Lorraine and Tournon; those on the side of the Protestants were Beza and Peter Martyr. After several meetings, disputes, and violent separations, the Protestant deputies declared their faith in the following words: "We confess, that Jesus Christ, in the Supper, does truly give and exhibit to us the substance of his body and blood by the efficacy of his Holy Spirit; and that we do receive and eat spiritually, and by faith, that very body which was offered and immolated for us, so as to be bone of his bone and flesh of his flesh, to the end that we may be enlivened thereby, and receive what is conducive to our salvation. And because faith, supported by the word of God, makes those things present which it apprehends, and by that faith

Supper. we do in deed and reality receive the true natural body and blood of Christ, by the power of the Holy Spirit; by this means we confess and acknowledge the presence of his body and blood in the Supper." One of the Romish delegates expressing his dislike of this last clause, the Protestant ministers gave the following explanation of their sentiments. "No distance of place can hinder us from communicating of the body and blood of Christ, for the Lord's Supper is a heavenly thing; and though on earth we receive with our mouths bread and wine, which are the true signs of his body and blood, yet by faith, and the efficacy of the Holy Ghost, our minds, which are fed with this food, are rapt up into heaven, and enjoy the presence of the body and blood; and that by this means it may be said that the body is truly joined to the bread, and the blood to the wine; but after the manner of a sacrament, and not at all according to place or natural position."²

If the reader can discover the precise meaning of these passages, his sagacity exceeds ours. That the Protestant deputies believed, or professed to believe, that the natural body and blood of Christ are by the faithful received in the Lord's Supper, is indeed evident; but their notions respecting the manner of this reception are very unintelligible, if not contradictory. In the former quotation, they confess that Christ's body and blood are really present in the sacrament; that they are made present by faith (we suppose the faith of the communicants); and that the very body which was offered and immolated for us is eaten spiritually and by faith. In the latter quotation, they seem to say that Christ's body and blood are in heaven, at a great distance from the true signs of them; that on earth the communicants receive only these signs, which are bread and wine; but that, by faith and the efficacy of the Holy Spirit, their minds, during actual communion, are rapt up into heaven, where they enjoy the presence of the body and blood; and that by this means the body and blood are truly joined to the bread and wine through the medium of the mind of the communicant, which is at once present both to the sign and to the thing signified. To this mysterious doctrine it is needless to urge objections. Every man who is accustomed to think, and to use words with some determinate meaning, will at once perceive that the authors of this declaration must have had very confused notions of the subject, and have pleased themselves with sound instead of sense, satisfied that they could not be wrong if they did not symbolize with the Lutherans or the council of Trent.

Of the churches of England and Scotland, in their established doctrines respecting the Lord's Supper, appear to be Calvinistical; but the compilers of the Thirty-nine Articles and of the Confession of Faith must have been much more rational divines than Beza and Peter Martyr. They agree in condemning the doctrine of transubstantiation, as contrary to common sense, and not founded in the word of God; they teach, that to such as rightly, worthily, and with faith, receive the sacrament, the bread which we break is a partaking of the body of Christ, and the cup of blessing a partaking of the blood of Christ; and they add, that the body and blood of Christ are eaten and drunk, not corporally or carnally, but only after a heavenly and spiritual manner, by which the communicants are made partakers of all the benefits of his death.³ In one important circumstance these two churches seem to differ. The Confession of Faith, as we understand it,⁴ affirms that in the Lord's Supper there is no sacrifice. The thirty-first article of the Church of England likewise condemns the Popish sacrifice of the mass, as a *blasphemous fable* and *dangerous deceit*; but in the *order for the administration of the Lord's Supper or Holy*

¹ Luther. Cogit. MS. 400. Gerhard. in Loc. Theol. de Sacra Coena.

² Thuanus, lib. xxviii. See also Johnson's Unbloody Sacrifice, vol. i.

³ Articles of the Church of England, art. xxviii.; and Confession of Faith, chap. xxix.

⁴ Chap. xxix. § 3.

Supper. *Communion*, the celebrator "beseeches God most mercifully to accept the alms and oblations of the congregation," and again "to accept *their sacrifice of praise* and thanksgiving:" from which petitions many have inferred that, in the Lord's Supper, that church offers a commemorative and eucharistical sacrifice. This inference seems not to be wholly without foundation. In the order for the administration of the Lord's Supper, according to the form of the Book of Common Prayer set forth by act of parliament in the second and third years of King Edward the Sixth, the elements were solemnly offered to God as a sacrifice of praise and thanksgiving; and though the prayer containing that oblation was, at the review of the liturgy some years afterwards, removed from the prayer of consecration, to which it was originally joined, and placed where it now stands in the post-communion service, yet the very act of parliament which authorized that alteration calls King Edward's "a very godly order, agreeable to the word of God and the primitive church, and very comfortable to all good people desiring to live in Christian conversation."

Some English divines hold the Lord's Supper to be a eucharistical sacrifice. The English church, however, has not positively determined any thing respecting this great question; and while she condemns the doctrine of the real presence, with all its dangerous consequences, she allows her members to entertain very different notions of this holy ordinance, and to publish these notions to the world. Accordingly, many of her most eminent divines have maintained that, in the celebration of the Lord's Supper, the elements of bread and wine are offered to God as a sacrifice commemorative of Christ's one sacrifice for the sins of the whole world; that these elements, though they undergo no substantial change, yet receive such a divine virtue by the descent of the Holy Ghost, as to convey to the worthy communicant all the benefits of Christ's passion; that they are therefore called his body and blood, because being, after their oblation, eaten and drunk in remembrance of him, they supply the place of his body and blood in the feast upon his sacrifice; and that it is customary with our Saviour to give to any thing the name of another of which it completely supplies the place, as when he calls himself the *door*¹ of the sheep, because there is no entrance into the church or kingdom of God but by faith in him. They observe, that the Eucharist's being commemorative, no more hinders it from being a proper sacrifice, than the typical and figurative sacrifices of the old law hindered them from being proper sacrifices: for as to be a type does not destroy the nature and notion of a legal sacrifice, so to be representative and commemorative does not destroy the nature of an evangelical sacrifice. To prove that, in the celebration of the Lord's Supper, there is a real sacrifice offered to God as well as a sacrament received by the communicants, they appeal to St Paul, who says expressly,² that "Christians have an *altar*, whereof they have no right to eat who serve the tabernacle," and who by contrasting the cup of the Lord with the cup of devils, and the table of the Lord with the table of devils,³ teaches plainly that those cups and those tables had the same specific nature. That the table of devils spoken of by the apostle was the Pagan altars, and the cup of devils the wine poured out in libations to the Pagan divinities, will admit of no dispute; and therefore, say the advocates for the eucharistical sacrifice, the table of the Lord must be the Christian altar, and the cup of the Lord the wine offered to God as the representative of the blood of Christ; otherwise there would not be that absurdity which the apostle supposes, in the same person drinking the cup of the Lord and the cup of devils, and partaking of the Lord's table and the table of devils. They observe further, that in all the ancient liturgies extant there is a

solemn form of oblation of the sacramental elements, and that all the Christian writers from the second century downwards treat of the Lord's Supper as a sacrifice as well as sacrificial feast, having indeed no value in itself, but acceptable to God as representing Christ's one sacrifice for the sins of the world. Our limits will not permit us to give even an abstract of their arguments; but the reader who shall attentively peruse Johnson's "Unbloody Sacrifice and Altar unveiled and supported," will discover that their notions are better founded than probably he supposes, and that they are totally irreconcilable with the doctrine of transubstantiation and the Popish sacrifice of the *mass*.

Other English divines of great learning, with the celebrated Hoadley bishop of Winchester at their head, contend strenuously that the Lord's Supper, so far from being a sacrifice of any kind, is nothing more than bread and wine reverently eaten and drunk, in remembrance that Christ's body was broken and his blood shed, in proof of his Father's and his own love to mankind; that nothing is essential to the sacrament but this remembrance, and a serious desire to honour and obey our Saviour as our head; that the sacrament might be celebrated without uttering one prayer or thanksgiving, merely by a society of Christians, whether small or great, jointly eating bread and drinking wine with a serious remembrance of Christ's death; that St Paul enjoins a man to examine himself before he eat of that bread and drink of that cup, not to discover what have been the sins of his past life in order to repent of them, but only that he may be sure of his remembering Christ's body broken and his blood shed; that, however, it is his duty in that, as in every other instance of religious worship, to resolve to obey from the heart every precept of the gospel, whether moral or positive; and that to partake worthily of the Lord's Supper is acceptable to God, because it is paying obedience to one of these precepts; but that no particular benefits or privileges are annexed to it more than to any other instance of duty. Bishop Hoadley acknowledges, that when St Paul says,⁴ "The cup of blessing which we bless, is it not the communion of the blood of Christ? the bread which we break, is it not the communion of the body of Christ?" he has been supposed by many learned men to affirm, that all the benefits of Christ's passion are in the Lord's Supper conveyed to the worthy communicant; but this, says he, is an idea which the apostle could not have in his thoughts as at all proper for his argument. The Greek word *κοινωνία* and the English *communion* signify only a partaking of something in common with others of the same society; and the apostle's meaning, he says, can be nothing more than that in the Lord's Supper we do not eat bread and drink wine as at an ordinary meal, but as memorials of the body and blood of Christ, in honour to *him* as the *head* of that body of which we are all *members*. That the word *κοινωνία* is not meant to denote any inward or spiritual part of the Lord's Supper, he thinks evident, because the same word is used with regard to the cup and the table of idols, where no spiritual part could be thought of, and in an argument which supposes an idol to be nothing.⁵

To this view of the nature and end of the Lord's Supper it must appear no small objection, that "he who eateth and drinketh unworthily is said to be guilty of the body and blood of the Lord, and to eat and drink a judgment to himself, not discerning the Lord's body." No doubt it would be sinful to eat and drink a mere memorial of Christ's death without serious dispositions; but we cannot conceive how a little wandering of the thoughts, which is all the unworthiness that the author thinks there can be on such

¹ St John x. 7.

² Heb. xiii. 10.

³ 1 Cor. x. 16, &c.

⁴ 1 Cor. x. 16.

⁵ Hoadley's Plain Account of the Nature and End of the Lord's Supper.

Supper.
and others,
a feast up-
on our Sa-
viour's sac-
rifice.

an occasion, should be a sin of so deep a dye as to be properly compared with the guilt of those who murdered the Lord of life. Other divines, therefore, feeling the force of this and similar objections, steer a middle course between the mere memorialist and the advocate for a real sacrifice in the holy Eucharist, and insist that this rite, though no sacrifice itself, is yet a feast upon the one sacrifice offered by Christ and slain upon the cross. The most eminent patrons of this opinion have been Dr Cudworth and Bishop Warburton; and they support it by such arguments as the following. In those ages of the world when victims made so great a part of the religion both of Jews and Gentiles, the sacrifice was always followed by a religious feasting on the thing offered; which was called the feast upon or after the sacrifice, and was supposed to convey to the partakers of it the benefits of the sacrifice. Now Jesus, say they, about to offer himself a sacrifice on the cross for our redemption, did, in conformity to general practice, institute the last supper, under the idea of a feast after the sacrifice; and the circumstances attending its institution were such, they think, that the apostles could not possibly mistake his meaning. It was just before his passion, and while he was eating the paschal supper, which was a Jewish feast upon the sacrifice, that our blessed Lord instituted this rite; and as it was his general custom to allude, in his actions and expressions, to what passed before his eyes, or presented itself to his observation, who can doubt, when, in the very form of celebration, we see all the marks of a sacrificial supper, but that the divine institutor intended it should bear the same relation to his sacrifice on the cross which the paschal supper then celebrating bore to the oblation of the paschal lamb? If this was not his purpose, and if nothing more was intended than a general memorial of a dead benefactor, why was this instant of time preferred for the institution to all others throughout the course of his ministry, any one of which would have been equally commodious? Indeed any other time would have been more commodious for the institution of a mere memorial; for the paschal lamb and unleavened bread were certainly a sacrifice; and the words used by our Saviour, when he gave the bread and wine to the apostles, were such as must necessarily have led them to consider that bread and wine as bearing the same relation to his sacrifice which the paschal supper bore to the paschal sacrifice. At that Jewish feast, it was the custom of every father of a family to break the unleavened bread, and to give to every guest a portion, saying, "This is the bread of affliction, which our fathers did eat in the land of Egypt;" a custom which we may be sure that Christ, as a father of his family, would religiously observe. The apostles knew well that they were not eating the identical bread which their fathers did eat in Egypt, but the feast upon the sacrifice then offered in commemoration of their redemption from Egyptian bondage; and therefore, when they saw their Master after supper break the bread again, and give it to each of them, with these remarkable words. "This is my body which is given for you, do this in remembrance of me," they must have concluded, that his meaning was to institute a rite which should to the end of the world bear the same relation to his sacrifice that the paschal supper bore to the sacrifice of the passover.

This inference, from the circumstances attending the institution, Bishop Warburton thinks confirmed by St Paul's mode of arguing with the Corinthians on their impiety and absurdity in partaking both of the Lord's table and the table of devils; for "what," says he, "had the eaters of the sacrifices to do with the partakers of the bread and wine in the Lord's Supper. if the Lord's Supper was not a feast of the same kind with their feasts? If the three feasts,

Jewish, Pagan, and Christian, had not one common nature, how could the apostle have inferred that this intercommunity was inconsistent? 'Ye cannot,' says he, 'drink the cup of the Lord and the cup of devils; ye cannot be partakers of the Lord's table and the table of devils.' For though there might be impiety in the promiscuous use of Pagan and Christian rites of any kind, yet the inconsistency arises from their having a common nature, and consequently, as they had opposite originals, from their destroying one another's effects in the very celebration. Sacrifices, and feasts upon sacrifices, were universally considered as federal rites; and therefore the Lord's table and the table of devils being both federal rites, the same man could no more be partaker of both, than he could at once engage to serve both God and the devil. This is the apostle's argument to the wise men to whom he appeals; and we see that it turns altogether upon this postulatam, that the Christian and Pagan feasts had the same specific nature, or were both feasts upon sacrifices. If this be admitted, it is easy to see why St Paul deemed those who ate and drank unworthily guilty of the body and blood of the Lord; for if the Lord's Supper be a feast upon his sacrifice, it must have been considered as the means of conveying to the communicants all the benefits of his death and passion; and the profanation of such a rite, by rendering his death ineffectual, might be fitly compared and justly equalled to the enormous guilt of those by whom his blood was shed." In reply to Bishop Hoadley's remarks upon the word *κοινωνία*, his brother bishop observes, that "had the apostle meant what the learned writer makes him to mean, he would doubtless have said *κοινωνία ὑμῶν εἰς τὸ σῶμα*, 'your communion in the body—your eating it jointly.' St Paul," continues he, "knew how to express himself properly, as appears from a passage in his epistle to the Philippians, where, professedly speaking of the joint participation of a blessing, he uses these words, *κοινωνία ὑμῶν εἰς τὸ εὐαγγέλιον*, 'your communion in the gospel.'" To the other remark, that no spiritual part could be thought of in the table of idols, because an idol is said by the apostle to be *nothing*, Bishop Warburton replies, "that by St Paul the Gentiles are said to have sacrificed to devils, and those who ate of such sacrifices to have had communion with devils; now the *devil*," continues his lordship, "was in St Paul's opinion *something*." But the inference which the apostle draws from the acknowledged truth, that the cup of blessing which we bless is the communion of the blood of Christ, and the bread which we break the communion of the body of Christ, puts his meaning, our author thinks, beyond all doubt. He says,¹ that the partaking of one bread makes the receivers of *many* to become *one body*. A just inference, if this rite be of the nature of a feast upon the sacrifice; for then the communion of the body and blood of Christ unites the receivers into one body, by an equal distribution of one common benefit. But if it be only a general commemoration of a deceased benefactor, it leaves the receivers as it found them, not one body, but many separate professors of one common faith.

Thus have we given such a view as our limits would permit us to give, of the principal opinions that have been held respecting the nature and end of the Lord's Supper. It is an ordinance which seems not to be generally understood; though, being intended to show forth the Lord's death till he come, it is surely of sufficient importance to engage the attention of every serious Christian. The most considerable English divines who have expressly written upon it are, Johnson in his *Unbloody Sacrifice*; Cudworth in his *Discourse concerning the true Nature of the Lord's Supper*; Hoadley in his *Plain Account*; and Warburton

Supper.

The ordi-
nance not
generally
under-
stood.

Supporters in his Rational Account. The notions of Cudworth and Warburton are the same, and perhaps they differ not so much from those of Johnson as many readers seem to imagine. At any rate, the arguments by which Warburton supports his doctrine must have some force, since it is said that Hoadley himself acknowledged they would be unanswerable, if it could be proved that the death of Christ was a real sacrifice. (H. H. H. H.)

SUPPORTERS, in *Heraldry*, figures in an achievement, placed by the side of the shield, and seeming to support or hold up the same. Supporters are chiefly figures of beasts: figures of human creatures for the like purpose are called *tenants*.

SUPPOSITORY, a kind of medicated cone or ball, which is introduced into the anus for opening the belly. It is usually composed of common honey mixed up with soap or oil, and formed into pieces of the length and thickness of the little finger, only pyramidal.

SUPRALAPSARIANS, in *Theology*, persons who hold that God, without any regard to the good or evil works of men, has resolved, by an eternal decree, *supra lapsum*, antecedently to any knowledge of the fall of Adam, and independently of it, to save some and to condemn others; or, in other words, that God intended to glorify his justice in the condemnation of some, as well as his mercy in the salvation of others; and for that purpose decreed that Adam should necessarily fall, and by that fall bring himself and all his offspring into a state of everlasting condemnation. These are also called *antelapsaries*, and are opposed to sublapsaries and infralapsaries. According to the supralapsarians, the object of predestination is, *homo creabilis et labilis*; and, according to the sublapsarians and infralapsarians, *homo creatus et lapsus*.

SURAJEGHUR, a town of Hindustan, in the province of Bahar, district of Monghier, sixty-eight miles east-south-east of Patna. Long. 86. 15. E. Lat. 25. 14. N.

SURAJEPOOR, a small town of Hindustan, in the province of Allahabad, fifty-one miles south-west by south from Lucknow, pleasantly situated on the west side of the Ganges.

SURAT, a large and populous city of Hindustan, in the province of Gujerat, situated on the south side of the Taptee river, about twenty miles above its junction with the sea. It is one of the largest cities in Hindustan; and is termed by Bishop Heber a very large and ugly city, with narrow winding streets, and high houses of timber-frames filled up with bricks, the upper stories projecting over each other. The city is about six miles in circuit, in the form of a semicircle, of which the river Taptee or Tuptee forms the chord. Near the centre of this chord, and washed by the river, stands a small castle, with round bastions, glacis, and covered way, in which are stationed a few sepoys and European artillerymen; and which is distinguished by the singularity of two flag-staffs, on one of which is displayed a union jack, on the other a plain red flag, the ancient ensign of the emperors of Delhi; an arrangement which was adopted in courtesy when the fort was conquered from the nawab of Surat, and was continued, though the nawab is only a pensioner on the bounty of the government. In the neighbourhood are most of the English houses of a good size. Without the walls is a French factory, containing some handsome and convenient buildings, but now quite deserted by their proper owners, and occupied by English officers. A French governor with several officers came to take possession of the factory, which was restored in 1814 at the conclusion of peace; but the governor died, and his suite was so thinned by disease that the survivors returned to the isle of Bourbon, and no one has appeared to supply their place. The city is protected on one side by a river; and on the other three sides by a brick rampart, or a ditch. The wall is entire and in good repair, with semicircular

bastions and battlements. There is also a strong citadel, erected on the bank of the river, and surrounded by an esplanade.

Surat formerly carried on a very extensive trade. In 1775 a greater quantity of ships belonged to the port than to Bombay. Large exports of cotton were formerly sent to China, but they are now chiefly sent by the way of Bombay. The trade has greatly declined, consisting of little but raw cotton, which is chiefly shipped in boats for Bombay. In manufactures the native artisan is now undersold by the English; a dismal decay, says Heber, has consequently taken place in the circumstances of the native merchants; and he mentions an instance of an ancient Mussulman family, formerly of great wealth and magnificence, who were reduced to dispose of their library for subsistence. The most thriving people in Surat are the Boras, or money-lenders, who drive a trade all through this part of India, and the Parsees. The last are the proprietors of half the houses in Surat. They are dexterous mechanics, good servants, and skilful merchants. They intermarry with each other, and retain all their ancient customs and prejudices, among which is their repugnance to extinguish fire, and the exposure of their dead to be devoured by birds of prey. The boats which lie in the river are of thirty or forty tons, with two masts. Vessels of greater burden must lie about fifteen miles off, below the bar, at the mouth of the Taptee; but few larger vessels ever come to Surat. There is a very neat and convenient church, as well as an extensive and picturesque burial-ground, full of large and numerous tombs of the former servants of the Company; most of them from 120 to 180 years old, and in the Mussulman style, with large apartments surrounded by vaults. There are no remarkable buildings in Surat. The nawab's residence is modern, but not particularly handsome. The British society is numerous and agreeable, this city being the station of a considerable force, of a collector, a board of customs, and the courts of justice. Of the ancient history of Surat under the Hindoo dynasties there are no authentic records. It was taken by the emperor Akbar in 1572, after a vigorous siege of forty-seven days. It was in 1664 taken and plundered by Sevajee, the great Mahratta chief, and was again visited by him in 1671, and laid under contribution, as it was by his successors in 1702 and 1707. Surat was surrendered to a British force in 1759 by the nabob, the ancestor of the present nawab, who was compelled to have recourse to foreign aid. He was succeeded by his sons, the last of whom agreed in 1800 to resign all his authority to the British for an annual pension of L.12,500. Surat is fifty-one miles south-west by south from Lucknow. Long. 73. 3. E. Lat. 21. 13. N. (F.)

SURCINGLE, a girdle with which the clergy of the Church of England usually tie their cassocks.

SURCOAT, a coat of arms, to be worn over body armour. The surcoat is properly a loose thin taffety coat, with arms embroidered or painted on it; such as is worn by heralds, and anciently used by military men over their armour to distinguish themselves by.

SURD, in *Arithmetic* and *Algebra*, denotes any number or quantity that is incommensurable to unity: it is otherwise called an *irrational number* or *quantity*.

SURDASTRUM, the ancient name of a drum used as an accompaniment to a pastoral pipe in a dance which was supposed to have the virtue of rendering harmless the bite of the tarantula.

SURDY, a small uninhabited island in the Persian Gulf, situated to the south of Kishme. Lat. 25. 54. N.

SURF is a term used by seamen to express a peculiar swell and breaking of the sea upon the shore. It sometimes forms but a single range along the shore, and at others three or four behind one another, extending perhaps half a mile out to sea.

Surat.

Surcingle
Surf.

SURGERY.

Surgery.

THE term *Surgery*, or *Chirurgery*, from *χειρ*, the hand, and *εργον*, work, originally signified, as its derivation implies, the manual procedure, by means of instruments or not, directed towards the repair of injury and the cure of disease; in contradistinction to the practice of *medicine*, denoting the treatment of disease by the administration of drugs, or other substances supposed to be of a sanative tendency. Such a meagre description applied but too justly to surgery in its infancy, and still more after its separation from its twin-sister medicine, in the twelfth century. When its practice was denounced by the Council of Tours as derogatory to the dignity of the sacred office of the priesthood, and beneath the attention of all men of learning, the term *chirurgery*, in its most literal interpretation, was quite sufficient to comprehend the duties of the degraded and uninformed surgeon, who had become a mere mechanic, attached to and completely dependent on the learned and philosophic physician. But the matured progress of the healing art has, fortunately for science and humanity, rendered such a definition of surgery in these days utterly untenable. Its complete separation from medicine would now be attended with the utmost difficulty; nor is it desirable that the attempt should be made, because its success, however partial and imperfect, would be most hurtful to both. They are now, and it is to be hoped will ever remain, one and inseparable. Their principles are the same throughout, and the exercise of their different branches requires the same fundamental knowledge; but their details are so numerous and intricate as to render it most difficult, if not impossible, for any one individual to cultivate all with equal success. The consequence has been, that while the theory and principles of physic and surgery remain united, as constituting one and the same science, the practical parts are now frequently separated into distinct professions, each person adopting that department most congenial to his pursuits, and for the management of which he conceives himself best qualified. The separation however is not that of acquirements, but merely of practice. It should never be forgotten, that the physician, before he can be either accomplished or successful in his profession, must be intimate with the principles, if not with the practice of surgery. And most certainly no one can ever lay just claim even to the title of surgeon, far less hope for eminence or success, unless he be equally qualified to assume both the appellation and the employment of the physician.

Many and laboured have been the attempts to define surgery according to its present state, so as to prevent interference with the department of physic. This example we will not follow. The arrangement as to what is medical, and what surgical, must in a great measure depend on custom, not on fixed and permanent rules. The paths of the practical surgeon and physician are distinct, but in their course they must often cross each other; and these collisions, so far from being avoided, ought rather to be sought, as probable sources of mutual benefit, so long as those enlightened feelings are entertained, and that honourable conduct pursued, which ought ever to distinguish the followers of a liberal, useful, and learned profession.

The limits allotted to this article not permitting us to enter into the details of surgery, we must content ourselves with a sketch of its history, and with some account of its improved condition as it is at present practised.

Origin.

That surgery is as old as man himself, that it was coeval with his fallen state, there can be little doubt. The fall entailed the frequent reception of injuries by external violence; and to assuage their pain and remove their in-

convenience, the ingenuity and contrivance of the sufferer were powerfully excited. Thus it would seem, that as to antiquity of origin, surgery must take precedence of medicine. And after wars and dissensions began to prevail, and wounds and injuries became both more frequent and more deadly, it is most probable that to these the practitioners of the healing art alone directed their attention, before the nature of disease began to be understood, or its cure was supposed to be within the reach of human means.

As to the state of surgery among the early Egyptians, we know but little, except that it was customary, in the time of Joseph, to embalm the dead; a process which appertains closely to both medicine and surgery. There are some grounds, however, for suspecting that they were more conversant with surgery than is generally supposed; for it is said that on "the ruined walls of the renowned temples of ancient Thebes, basso-relievos have been found, displaying surgical operations, and instruments not far different from some in use in modern times." Their medical practice, entirely founded on incantation and astrology, was sufficiently simple. They divided the body into thirty-six parts, believing in an equal number of demons, to whom those parts were intrusted, and to invoke whose aid in sickness was the principal duty of the physician, each spirit being called upon to cure his own peculiar portion.

Among the Jews, the operation of circumcision was performed, no doubt skilfully and dexterously, though with rude implements, by the priesthood, an order which, for many ages, and in many climes, conjoined the cure of the body with that of the soul.

The earliest notice of this art is from the ancient Greeks, who, it is probable, had derived their medical traditions from the Egyptians. They considered medicine to be of divine origin; and its first professors, as they inform us, were no less personages than gods and sons of gods.

Medicine and surgery, at their origin, were conjoined; and both continued to be practised indiscriminately, until separated by the Arabian school. Their complete estrangement occurred, as we have already stated, about the middle of the twelfth century. At first, surgery chiefly occupied the attention of the ancient leech, as the more certain and more obviously useful branch of his profession; but ultimately it became very secondary to medicine when dignified by philosophy and priestcraft.

Chiron the Centaur, born in Thessaly, is presumed to have been the father of surgery, celebrated for skilfully applying soothing herbs to wounds and bruises. But his fame is somewhat endangered by that of *Æsculapius*, the son of *Apollo*, by some held to be the pupil of Chiron, by others, his predecessor and superior. *Æsculapius* is supposed to have been deified, on account of his skill, about fifty years before the Trojan war. His very existence however has been questioned. *Apollo* was the original god of physic among the early Greeks; but he appears to have resigned in favour of *Æsculapius*, whose temples became the depositories of medical and surgical knowledge; more particularly those of *Epidaurus*, *Cnidos*, *Cos*, and *Pergamus*.

Certain it is, according to the testimony of *Celsus*, that *Podalirius* *Æsculapius* is the most ancient authority in surgery. His immediate descendants, two sons, *Podalirius* and *Machaon*, have been immortalized by *Homer*. They followed *Agamemnon* to the Trojan war, and there their services were so highly valued as to secure them a not unobscure niche among the heroes of the *Iliad*. Of the two, *Machaon* seems to have been the more distinguished. When he is wounded by *Paris*, the whole army is represented as interested in

Surgery.

Early Egyptians.

Jews.

Greeks.

Chiron.

Æsculapius.

Podalirius and Machaon, B. c. 1192.

Surgery. his recovery. Even the stern Achilles inquires anxiously after "the wounded offspring of the healing god;" and the valiant Nestor, to whose care he is intrusted, is exhorted to unwonted exertion in his behalf; "for a leech who, like him, knows how to cut out darts, and relieve the smarting of wounds by soothing unguents, is to armies more in value than many other heroes." Podalirius enjoys the distinction of being reputed the first of phlebotomists, and probably the most successful, from his time to this; having opened a vein in either arm of the king of Caria's daughter, who had been severely injured by a fall from the house-top, having, after her recovery, been rewarded with the hand of the fair princess, and having been presented by her munificent father with the Chersonese as her dowry. As to medicine, they seem to have been either ignorant, or in no great repute; for, on the breaking out of pestilence in the Grecian camp, Homer neglects them entirely, and applies at once to Apollo. And even their surgical attainments, for which they are celebrated by him, seem to have extended no farther than to the simple extraction of darts and other offensive weapons, the checking of hæmorrhage by styptics or pressure, and the application of lenitive salves. The poet takes notice of his warriors sustaining fracture of the bones; but in such emergencies he adopts the same course as in the pestilence, and invokes the aid of the non-professional deities; from which circumstance we may infer, that in those days surgery had made but little advancement.

Asclepiades. For upwards of 600 years after the Trojan war, there are scarcely any accounts of medicine and surgery. They seem to have remained strangely stationary during the whole of that period. Their practice was confined to the Asclepiades, or reputed descendants of Æsculapius; whose lore was orally communicated from father to son in that family, until they received an extraordinary impulse from the great Hippocrates, himself a branch of the family, and said to have been the fifteenth in lineal descent from the deified founder. The Asclepiades, in the course of their monopoly, established three schools of medicine, at Rhodes, at Cnidos, and at Cos. The last gave Hippocrates to the world, and thus attained a proud and enduring pre-eminence.

Pythagoras, B. c. 600. Pythagoras was the first who brought philosophy to bear upon the practice of the healing art, and led the way in raising it to the dignity of a science. Democritus, the happy sage, likewise turned his attention to medicine as a branch of general philosophy, and pursued it zealously. He lived in terms of friendship with Hippocrates, by whom he was held in great respect. By Pythagoras a school at Crotona was founded, about the time of Tarquinius Superbus, espousing doctrines somewhat different from those of Cos and

Damocedes. Cnidos. It produced Damocedes, a contemporary of Pythagoras, who seems to have practised in Athens, an honoured and successful surgeon. By Polycrates, king of Samos, he was presented with two talents of gold for having cured him of a troublesome distemper. He was afterwards taken captive by the Persians. Their king, Darius, was intrusted to his care for a dislocated ancle, as well as the queen, Atossa, for a cancer of the breast; and he was soon loaded with honour and wealth on account of his wonderful cures, performed after the Egyptian physicians, previously in attendance, had signally failed.

But we cannot suppose such men as Damocedes and the Asclepiades to have attained any great proficiency in surgery; for the touch of a dead body was interdicted as a profanation both by Jew and Greek, and consequently they must have been almost entirely ignorant of anatomy. They may have understood something of the skeleton, from their practice amongst fractures and dislocations; and they may have formed some general idea of the viscera, from researches in comparative anatomy, and from instruction by the Egyptians, whose practice in embalming afforded ample scope for observation. But the minute structure of the

human body must have been to them a profound mystery. **Surgery.** And, knowing that anatomy is, was, and ever must be, the foundation of true surgical knowledge, we cannot evade the conviction that surgery, though occasionally successful and honoured in ancient times, must have been nothing more than a rude, imperfect, and uncertain art. The practice of its professors seems to have been extremely limited, consisting of little more than the binding up of wounds, and the staunching of hæmorrhage by styptics and the cautery; the extraction of darts and other missiles from the wounds which they had inflicted; phlebotomy, both general and local; and cupping by scarification. Whether they practised the capital operations or not, we are not informed; but it is probable that their comparative ignorance of anatomy effectually deterred them from any extensive division of the soft parts, as extremely hazardous and uncertain.

Hippocrates, born in the 80th Olympiad, upwards of 400 years before the Christian era, did more for medicine and surgery than all who had preceded him; and indeed few of those who have succeeded him have been of equal service to the profession. He soon freed medicine in a great measure from the absurdities with which ignorance and superstition had invested it; and through a long, honoured, and glorious life he set a splendid example of persevering industry, philosophical research, and high moral worth. His fame soon raised the Coan school far above its rivals. Though his anatomical knowledge seems little better than a blending of ingenuity with error, yet he appears to have had some indistinct notions of the circulation of the blood; but Dr Pitcairne, in his "Solutio Problematis de Inventoribus," has sufficiently evinced that he was very far from anticipating the great discovery of Harvey. With all his deficiencies, and notwithstanding all the disadvantages under which he laboured, so correct was his observation, and so faithful his chronicling of disease, that many of his descriptions may be fairly inserted in our modern nosologies. Though his attention was chiefly directed towards the improvement and promotion of physic, now begirt with philosophy, and studied as a science, and though his practice was principally confined to the treatment of internal disease, yet he was not wholly inattentive to surgery. And his practice seems to have been tolerably bold and decisive; for, in regard to external disease, it was with him a maxim, that "when medicine failed, recourse should be had to the knife, and when the knife was unsuccessful, to fire;" a substance of which all the ancient doctors seem to have been particularly fond, from Prometheus downwards. Hippocrates employed it not only in a variety of diseases, but in various forms. Sometimes he applied red-hot irons to the part; sometimes he raised a conflagration on it, and of it, by a piece of wood dipped in boiling oil, or by burning a roll of flax after the manner of the modern moxa. He also made use of tents and issues, as more gentle means of counter-irritation. He seems to have performed the capital operations with boldness and success, excepting lithotomy, the practice of which appears to have been confined to a few who made it their exclusive study. He however recommends the removal of calculus, large and firmly lodged in the kidney, by incision; adding, probably in apology for the daring of the procedure, that otherwise there are no hopes of a cure, and that the disease must prove fatal. He reduced dislocations, and set fractures, but clumsily and cruelly; extracted the fœtus with forceps when necessary; and both used and abused the trepan, employing it not only in depression and other accidents of the cranium, but also in cases of headach, and other affections to which the operation was inapplicable. In cases of empyema and hydrothorax, after ascertaining by percussion that fluid was present in the cavity of the chest, he did not hesitate to make an incision between the ribs; and having allowed part of the fluid to escape, he placed a tent in the wound, and by withdrawing it regularly once a day, the whole was ulti-

Surgery. mately evacuated. He seems to have been perfectly acquainted with tetanus and spontaneous gangrene; observing, that even minute wounds of tendinous parts, as the fingers and toes, sometimes produce convulsions which terminate fatally; and that black spots on the feet frequently increase to extensive gangrene and incurable mortifications. Some of his practices have been long and justly exploded, some have been successfully continued, and others have, after disuse, been revived as modern inventions. For example, his method of ascertaining the presence or absence of fluid in the chest was by percussion, and applying the ear to the part, thus anticipating the use of the modern stethoscope. One of his modes of counter-irritation, we have seen, was by burning flax on the part, as in the modern moxa; and he strongly recommends the production of eschars on the back and breast in the earlier stages of pulmonary disease, thus anticipating the supposed valuable discoveries of a celebrated modern charlatan. His writings are elegant, and well repay a careful perusal. By them he made posterity his debtor; his contemporaries were not insensible to his merits, and endeavoured to reward them during his life. The inhabitants of Argos voted him a statue of gold; he was more than once crowned by the Athenians, and, though a stranger, was initiated into the most sacred mysteries of their religion, the highest distinction which they could confer; after his death, universal and almost divine honours were paid to his memory; temples were erected to him, and his altars covered with offerings.

We have already seen that surgery had long been stationary before the time of Hippocrates; and it made but little advancement during many succeeding generations. The Asclepiades had confined the knowledge of medicine among themselves; Hippocrates, however, gave oral instructions in anatomy and the art of healing, and thus disclosed its mysteries to the world. But few of his disciples seem to have profited much by his liberality. One of them, his kinsman Ctesias, we are told, acquired considerable renown for his skill; and having been taken prisoner by Artaxerxes Mnemon, in a battle fought against his brother Cyrus, was successful in curing him of a severe wound, and thus obtained favour with his captor. Plato began to flourish about this time; but though he was connected with medicine, we cannot lay claim to him as eminent in surgery; and he was more famous for his philosophy than his physic. Perhaps the most distinguished in surgery, among the more immediate successors of Hippocrates, was Diocles Carystus. He devoted more attention to anatomy than any of his predecessors, was curious in bandaging wounds of the head, and invented the bellulon, an instrument for extracting darts. Carrying his surgery into the practice of medicine, he was not very happy in the result; from observing that external wounds, abscesses, and inflammations were attended with fever, he supposed that general fever was uniformly occasioned by one or more of these causes operating internally. He followed Hippocrates in practice, and, like him, cultivated his profession, "not for lucre or vain-glory, but from real love of the medical art, and a pure spirit of humanity." Praxagoras of Cos was the last of the Asclepiades who succeeded in leaving a name behind him. As a surgeon he is reported to have been bold in the extreme, incising the fauces freely, and excising portions of the soft palate, in bad cases of cynanche; and making incisions into the bowels to remove obstructions, when milder measures failed. Aristotle, the celebrated preceptor of Alexander the Great, although not strictly in the medical profession, was the promulgator of doctrines which for a long time had a powerful effect on medicine. While he followed out the general principles of the healing art, and

was curious in anatomical research, he seems to have disdained to meddle with the practical details, and among the rest those of surgery. **Surgery.**

On the dismemberment of the vast empire of Macedo-Egypt. nia after the death of Alexander the Great, learning took up its chief abode at Alexandria, under the protection of Ptolemy Soter. And here it was that popular prejudice **B. c. 300.** first gave way, and permitted the examination of dead bodies, the greatest possible boon to the medical profession, inasmuch as it removed what had hitherto been the most serious obstacle to its advancement, ignorance of human anatomy. Herophilus and Erasistratus, the two great heads of the Egyptian medical school, were the first who had an opportunity of practising human dissection, the bodies of criminals having been given to them for that purpose; and they consequently not only corrected many errors, but made numerous and important discoveries, in anatomy; thus imparting a fresh stimulus, and affording a new and more solid basis to both medicine and surgery. By some they have been accused of carrying their enthusiasm in this inquiry to such an extent as to "open the bodies of living criminals for the furtherance of their physiological views;" but this is probably a mere exaggeration, originating in the horror with which human dissection was at first regarded; a horror which unfortunately is not even in our day altogether extinguished, notwithstanding the recent legislative enactments in favour of anatomical research. But we find even these privileged men falling into most palpable mistakes; for example, Herophilus plainly confounds the tendons and ligaments with the nerves. Yet the fact that the names which he gave to many parts still remain in use, will of itself remind posterity how much they are indebted to him for his anatomical labours. He was likewise one of the greatest surgeons of ancient times, and, as well as Erasistratus, acquired as much fame for brilliant cures as for anatomical knowledge. The surgical practice of the latter was characterized by peculiar boldness and decision, and strongly marked with the failing of his time and school, a love of multiplying and inventing murderous implements, and the relentless use of them. "In schirrosities and tumours of the liver, he did not scruple to make an ample division of the integuments, and try applications to that viscus itself. He followed the same practice in diseases of the spleen, which he regarded as of little consequence in the animal economy." And perhaps he was right in his supposition, though not in his practice. In cases of retention of urine, he made use of the particular catheter which long bore his name. Xenophon of Cos, said to have been a follower of Erasistratus, seems to have been among the first who arrested hæmorrhage from a member, by encircling it tightly with a ligature. Mantius, a pupil of Herophilus, wrote a treatise on surgical dressings, which he rendered complicated in the extreme. Another, Andreas of Carystus, wrote on the union of fractured bones, and invented several ponderous machines for reducing luxations of the femur. Indeed the surgeons of the Alexandrian school were all distinguished by the nicety and complexity of their dressings and bandagings, of which they invented a great variety. Among them, as in the time of Hippocrates, lithotomy was practised by particular individuals, who devoted themselves exclusively to that operation; and we are told that one of them, Ammonius, employed an instrument, by means of which he broke down stones in the bladder, plainly anticipating Civiale, and furnishing a marked example to the present age of the truth of Solomon's apophthegm, that "there is nothing new under the sun."¹ It is not improbable that some of their other practices might have afforded equally

¹ A curious illustration of this is given by Dr James Johnson, in the narrative of his visit to Pompeii. "The Dilator or Speculum, for which Mr Weiss of the Strand obtained so much repute a few years ago, has its exact prototype in the Bourbon Museum at Naples. The coincidence in such an ingenious contrivance would be absolutely miraculous; but unfortunately there is a key to the similitude, which de-

Surgery. striking examples of this sometimes unpalatable truth; but unfortunately the greater part of the writings of the Alexandrian school perished in the conflagration of the famous national library in the time of Julius Cæsar; a calamity fraught with immense loss to the healing art, as well as to almost every other branch of knowledge.

Rome. The arts and sciences followed the seat of empire in its transfer to Europe under Julius Cæsar, and Rome became the grand centre of intellectual illumination. Notwithstanding the shrewd sense displayed by the ancient Romans in most matters, it is strange, yet true, that for centuries all ranks of society, from the mere plebeian rabble to the censor, had entertained an abhorrence of all practitioners of medicine and surgery, and trusted for cures to spells and incantations. Indeed public edicts were issued, "discouraging all countenance to the professed exercise of physic, and recommending faith in traditionary prescriptions and religious rites." Cato the censor managed the sick of his own family according to the terms of this edict, and gravely wrote down the words of incantation for curing dislocation or fracture. For nearly the first 600 years of its existence, Rome, accordingly, had no regular practitioner of medicine. The first we read of was Archagathus, a Greek, from the Alexandrian school, who practised in Rome, chiefly as a surgeon, during the consulates of Lucius Æmilius and Marcus Livius. At first his surgical skill obtained for him no inconsiderable fame, but the ancient prejudice soon revived in full vigour. An enraged populace—perhaps not without some reason, for he seems to have been particularly fond of the knife and cautery—compelled him not only to suspend his practice, but, changing his original title of "healer of wounds" to that of "executioner," caused him to be banished from the Roman capital. Afterwards, however, a native of Bithynia, assuming the name of Asclepiades, established himself in tolerable repute by virtue of insinuating manners, shrewd common sense, and the performance of several fortunate cures "tuto, cito, et jucunde." But with him we have little concern, for his sagacity soon taught him that it was essential to his welfare to avoid the unpopular practice of surgical operations, and accordingly he confined himself entirely to the apparently less hurtful administration of medicine. The only important traces of his surgical practice are, that in ascites he practised and recommended discharge of the accumulated fluid by minute punctures of the abdominal parietes; and that for quinsy, which term probably comprehended many of the various acute diseases of the throat now known and distinguished, he not only employed bold blood-letting, local and general, by the lancet and by cupping, but also had recourse to scarification of the fauces, and even attempted laryngotomy. By novel and successful cures in his medical practice, and frequent indulgence in skilful quackery, he obtained great personal reputation, and so far overcame popular prejudice as to establish a tolerably fair field in Rome for future practitioners. He was the contemporary of Cæsar, and the personal friend of Cicero. The latter is eloquent in his praise, and through him seems to have formed a high estimate of the medical

character. "Nothing," says he, "brings men nearer to the gods, than by giving health to their fellow-creatures." It would thus seem that, in his time at least, the ancient grudge against the doctors had abated in Rome. Among the disciples and immediate followers of Asclepiades was Cassius, described as Iatro-Sophista, who left behind him several works on anatomical and surgical subjects. In one of the latter he distinctly accounts for wounds on one side of the head producing paralysis on the other, from the decussation of the nerves; a tolerable proof that he was not only a good anatomist for the time, but also an observant practitioner.

Rome itself did not produce a single medical practitioner of any reputation before the age of Aulus Cornelius Celsus, although he himself chooses to be complimentary to some of his immediate predecessors, "Tryphon, Euelpistus, and Meges, the most learned of them all." Celsus, the contemporary of Horace, Virgil, and Ovid, likened to Hippocrates for the quantity of his sound practical information, and to Cicero for the elegance of his style, lived in the reigns of Tiberius, Caligula, Claudius, and Nero, in the beginning of the first century of Christianity, upwards of 150 years before Galen.¹ In his celebrated medical work, he places great reliance on Hippocrates and Asclepiades, more particularly the latter, and gives a complete and excellent digest of all the true medical and surgical knowledge of his times, although it is not certain that he himself either practised medicine or operated in surgery. "Of his surgical operations and remarks, many are yet far from being obsolete, and impress us with a high idea of his ingenuity and judgment. His mode of performing lithotomy (on the gripe) has been in recent times warmly defended by Heister, especially as applicable to children. He describes the operation for cataract by depression, and the method of forming an artificial pupil. The whole of his account of injuries of the head is admirable, and evinces wonderful tact and discrimination. His rules for distinguishing fracture, and for the application of the trepan, have been highly eulogized; nor is what he says about contrecoups less accurate. He is the first who has remarked that there may be rupture of a vessel within the cranium without fracture or depression." And he is the first who recommended the application of ligatures to a wounded artery, with the view of arresting its hæmorrhage, after pressure has failed. He improved amputation, an operation then not much in use; and recommended its adoption in cases of gangrene from external causes. He is minute in his details as to the treatment of fracture and dislocation; his description of carbuncle is good, and its treatment similar to that now pursued, namely, free application of the strongest escharotics to the gangrened part. He describes several species of hernia, and gives directions for their reduction. "It would be endless however to particularise. Whoever wishes to know the exact state of surgical knowledge in the world at the time of the Cæsars, may turn to the pages of Celsus, with the hopes of a gratification which will not be disappointed."²

Aretæus, born in Cappadocia, practised in Rome, proba-

stroys the charm of astonishment. A crafty Frenchman imitated from memory, and with some awkward deviations, the Pompeian Speculum, and passed it off as his own. Weiss improved upon the Frenchman, and hit upon the exact construction of the original! Many modern discoveries may probably have originated in the same way."

¹ A life of Celsus by Joannes Rhodius is subjoined to the second edition of a work of that learned Dane, entitled "De Acia Dissertatio, ad Cornelii Celsi mentem, qua simul universa Fibulæ ratio explicatur." Hafniæ, 1672, 4to. We must likewise refer our philological readers to "Jo. Baptistæ Morgagni in Aur. Corn. Celsum et Q. Ser. Samonicum Epistolæ, in quibus de utriusque Auctoris variis Editionibus, Libris quoque manuscriptis, et Commentatoribus disseritur." Hagæ-Com. 1724, 4to. The prænomen of Celsus appears to have been Aulus, and not Aurelius, which is a "nomen gentile." See Fabricii Bibliotheca Latina, tom. ii. p. 37. edit. Ernesti.

² He relates an interesting anecdote of Hippocrates, illustrative of his abuse of the trepan. "Knowing and skilful as he was, he once mistook a fracture of the skull for a natural suture; and was afterwards so ingenuous as to confess his mistake, and leave it on record." To this he adds, "This was acting like a truly great man: little geniuses, conscious to themselves that they have nothing to spare, cannot bear the least diminution of their prerogative, nor suffer themselves to depart from any opinion which they have embraced, how false and pernicious soever that opinion may be; while the man of real ability is always ready to make a frank acknowledgement of his errors, especially in a profession where it is of importance to posterity to read the truth:" a moral which cannot be too often forced upon the attention of the present generation.

Surgery. bly about the time of Domitian. He was the first who made use of blisters, using cantharides for that purpose. Dissection in his time was prohibited under the severest penalties: his anatomical knowledge was therefore neither profound nor exact; "nevertheless he had the sound penetration to regard anatomy as the only legitimate basis on which either medical or surgical science could rest." Heliodorus, the celebrated physician of the emperor Trajan, has left some excellent observations on injuries of the head; and Antyllus, almost a contemporary, was a zealous and successful surgeon. He boldly recommends bronchotomy in cases of threatened suffocation induced by disease of the throat; and, in inflammatory affections of emergency, advises arteriotomy in preference to venesection, showing that excessive loss of blood thereby need not be dreaded, it being readily prevented by dividing the artery completely across. He also alludes to the operation for cataract by extraction, which he however recommends very cautiously, and only when the cataract is small. He obtained the radical cure of hydrocele by free incision of the parts. Rufus the Ephesian, who seems also to have lived in the time of Trajan, was a zealous anatomist and surgeon, and has left a treatise on diseases of the kidneys and bladder. About the commencement of the second century, Archigenes the Syrian settled in Rome, and distinguished himself both in medicine and surgery. His writings, which were chiefly confined to the latter subject, are unfortunately lost. Between Celsus and Galen, however, we meet with no great Roman writer on medicine or surgery. These were among the last of the liberal arts that were encouraged by the Romans; and the proud patricians refusing to educate any of their family to such a profession, the medical practitioners of Rome were at first importations from Greece and Alexandria, and afterwards self-educated slaves and freedmen.¹

Rufus, A.D. 96-117. Claudius Galenus was born at Pergamus, in Asia Minor, in the 131st year of the Christian era. After studying at Smyrna and Corinth, he completed his medical education at Alexandria, and ultimately settled in Rome, where he soon obtained a great reputation, both as a successful practitioner, and as a public lecturer on anatomy. Professional jealousy of his talents, however, drove him from Rome, to which he did not return until recalled by Marcus Aurelius. Shortly afterwards he was appointed physician to the young emperor Commodus, with whom, as well as with the public, he rose to great favour. A man of great erudition, brilliant genius, and indomitable industry, he produced works which exerted a most powerful and extensive influence over medical practice. He has the merit of rescuing medical inquiry from the chaos in which he found it, and restoring it to the paths of light and nature. His fame indeed was so great as to prove, in one sense, detrimental to the advancement of the medical profession, inasmuch as his opinions were received as oracular in the schools of all the civilized countries for no less a period than 1300 years, thus seriously retarding further investigation. His works were both numerous and elaborate; but unfortunately he seems to have been debarred from the study of the groundwork of his profession, human anatomy. His dissections appear to have been limited to the simiæ and other mammiferous animals, as most resembling the human structure, though on one occa-

Surgery. sion "he felicitates himself on the opportunities he had enjoyed of examining two skeletons preserved in Alexandria, and recommends all anxious to obtain a thorough knowledge of osteology to repair to that city." In his early years, he practised surgery at Pergamus with marked success; but in Rome he seems to have confined himself almost entirely to medicine, excepting the occasional performance of phlebotomy: probably the valorous Romans had not yet lost their hatred and dread of the terrible operations of surgery. Like others, however, he was still so much of a general practitioner, as to practise pharmacy as well as medicine, with a little of surgery; and he himself informs us, that he had a drug-shop in the Via Sacra. "He established two general principles as the basis of all surgery—synthesis, or the reunion of parts—diæresis, or their complete division, as by amputation or extirpation. In four cases he detected luxation of the femur backwards, a variety not mentioned by Hippocrates; and records two instances of spontaneous luxation of the same bone. He also treats of more than one species of hernia. But although in his writings we meet with a few bold chirurgical attempts, as in the application of the trepan to the sternum in a case of empyema, yet it must be confessed that by far the greatest part of his surgery seems to have been confined to fomentations, ointments, and plasters, for external affections, together with the art of bandaging, a love for which he necessarily acquired at the Alexandrian schools; and the employment of complicated machinery in fracture and dislocations." His researches were not limited to medical science, but comprehended literature and philosophy.²

The early Christians unfortunately appear to have injured medicine and surgery, by attributing to martyrs and their relics the power of healing wounds and curing diseases; "acknowledging the active interference of demons and blessed spirits in the affairs of men, and leaving true philosophy in total abandonment." A Cimmerian gloom was then fast overspreading the world, by which science and art were destined to be long obscured; and shortly after the time of Galen, we accordingly find the medical along with the other sciences encompassed by the dark clouds of ignorance and barbarism. One or two names however occur worthy of notice, but more from having preserved than advanced medical knowledge. Oribasius, a pupil of Zeno, lived in the time of the emperor Julian, whose friendship he enjoyed, and became a celebrated practitioner, as well as of great importance in the state. His works are principally compilations, though judicious and useful. His surgery is marked with timidity, discouraging operations, except in most extreme cases, and is chiefly confined to unguents and embrocations. He abstracted blood locally, by making deep and extensive scarifications, or rather incisions, with the knife; a proceeding somewhat resembling the important modern improvement in the treatment of erysipelas, but adopted under different circumstances, and with other objects in view.

During the fifth century the west was repeatedly invaded by the Huns, Goths, Alans, and Lombards. Science greatly suffered in consequence; and no name worthy of remembrance is to be found, until, nearly two centuries after Oribasius, appeared Aëtius, a native of Amida, and a pupil of the

¹ On this subject, a remarkable controversy took place in England during the earlier part of last century. It was occasioned by Dr Mead's "Oratio Anniversaria Harveiana, in Theatro R. Medicorum Londinensium Collegii habita, ad diem XVIII. Octobris, MDCCXXIII. Adjecta est Dissertatio de Nummis quibusdam a Smyrnæis in Medicorum honorem percussis." Lond. 1724, 4to. This was followed by a publication of Dr Middleton, "De Medicorum apud veteres Romanos degentium Conditione Dissertatio; qua, contra viros celeberrimos Jacobum Sponium et Richardum Meadium, servilem atque ignobilem eam fuisse ostenditur." Cantab. 1726, 4to. To this dissertation Dr Ward of Gresham College published an answer in 1727: Middleton published the first part of a defence in 1728, and Ward having rejoined in the course of the same year, his antagonist prepared a second part, of which Dr Heberden printed a few copies in 1761, eleven years after the author's death.

² Here we must refer our classical readers to a most important collection published under the title of "Medicorum Græcorum Opera quæ exstant. Editionem curavit D. Carolus Gottlob Kühn, Professor Physiologiæ et Pathologiæ in Literarum Universitate Lipsiensi Publicus Ordinarius." Lipsiæ, 1821-30, 26 tom. 8vo. Three of the volumes are each divided into two parts. This collection includes the works of Hippocrates, Aretæus, Dioscorides, and Galen. Dioscorides was edited by Sprengel, and the other writers by Kühn.

Surgery. Alexandrian school. "His surgical writings are copious and valuable. His opinions were guided by experience, and his methods of management and cure are characterised by much caution and discrimination. We find a variety of surgical queries and suggestions which had escaped Celsus and Galen, as well as the description of several diseases which have been omitted by Paulus Ægineta. He recommended and practised scarification of the legs in anasarca, and made free use of both the actual and potential cauteries; he cut out hæmorrhoidal tumours; operated for aneurism; tried to dissolve urinary calculi by the administration of internal remedies; and has given a series of interesting chapters on inflammation of the intestines followed by abscess, on encysted tumours, on the varieties of hernia, on diseases of the testicle and castration, on the pricks of the nerves and tendons, and in fact on almost every important branch of surgical knowledge. If, mixed up with these, we find some things which the matured experience of ages has abolished, it is less to be marvelled at, than that surgery was already enriched with so many valuable facts and observations." He makes no reference to the reduction of fractures and dislocations, whence it has been plausibly inferred, "that in all likelihood quacks were at that time in complete possession of this branch of practice. Better were it for society that it was quite out of their hands now!" He seems to have been the first to open up a field of medical inquiry, which has since been so successfully cultivated,—the nature and composition of urinary calculi. He appears also to have turned much of his attention to diseases of the eye, and is the first who speaks of the dracuncululus or Guinea-worm. Alexander of Trallis, a famous physician in the time of Justinian, about the middle of the sixth century, was an author of more originality than either Oribasius or Aëtius. He wrote on diseases of the eye, and on fractures; but both treatises have been lost, which is the more to be regretted, as, with this exception, he confined himself entirely to internal disease. The celebrated Paulus Ægineta, also of the Alexandrian school, lived about the middle of the seventh century, and made both large and valuable contributions to surgery. He frequently performed the operations which he describes, and abandoned the labours of the mere theorist, for the more valuable results of practical observation and experience. "His sixth book has been considered by many, and not without reason, as the best body of surgical knowledge, previous to the revival of letters." He recommended bleeding from the immediate neighbourhood of the part affected, in preference to general blood-letting, because more effectual; and, for the like reason, opened the temporal artery in cases of very severe ophthalmia. He had recourse to copious venesection, with the view of accelerating painful descent of calculus in the ureter. He opened internal abscesses by caustics, and defined the points at which he thought it advisable to perform paracentesis in the different alleged species of ascites. In lithotomy, having first endeavoured to ascertain the situation of the calculus by the rectum, he made his incision, not in the centre of the perineum, as recommended by Celsus, but to one side of the raphe, as is now practised. Of the impropriety of extensive incision of the bladder he seems to have been well aware, directing that the external wound should be much freer than the internal, and that the latter should be in extent merely sufficient to admit of the passage of the stone. While Celsus limited the operation to patients between nine and fourteen

years of age, he sanctions its performance after the age of puberty, but admits that the chances of success increase with the youth of the patient. He described more than one variety of aneurism, pointing out those cases in which he thought it advisable to attempt a cure by operation; and extended this to the aneurisms of the head and joints, excepting only those of the groin, arm-pit, and neck, instead of confining it to the tumours of the arm alone, as had been done by Aëtius. All aneurisms, excepting aneurism by anastomosis, which he clearly and accurately distinguished, he conceived to originate in rupture of the coats of the artery. He performed extirpation of the mamma by crucial incision, and practised both laryngotomy and tracheotomy. He is the first who seems to have performed the latter operation as a means of carrying on respiration during occlusion of the larynx, but naturally enough falls into the error of transverse instead of longitudinal incision. He describes different species of hernia, and did not hesitate to operate when the tumour became strangulated. He is also the first who treats of fracture of the patella. He was pre-eminent as an accoucheur, and was the originator of the obstetric operation of embryotomy.¹ From the time of Paulus, we find no Greek or Roman surgeon of note, until the appearance of Actuarius, a Greek, who practised with great distinction at Constantinople, probably about the beginning of the twelfth century, but at what exact period it is impossible to ascertain. Among his writings are found several surgical treatises, which however possess no greater merit than as compilations from previous authors.²

Having thus traced surgery from its origin, through the Egyptian, Greek, and Roman dynasties, we come to notice the prolongation of its feeble existence in Arabia.¹ From Alexandria, captured by the Saracens under Amrou in 640, knowledge was gradually communicated to Arabia. Its people became acquainted with medicine through the medium of translations of the Greek authors; and the "seat of learning was transferred, for a time, from beneath the shadow of the cross to the empire of the crescent; from the classic shores of Italy and Greece, to the warlike followers of Mahomet, and the fiery descendants of Ishmael." Many valuable manuscripts, rescued from the savage destruction of the Alexandrian library, were carefully transcribed, or translated into the Syriac or Arabic languages, and dispersed in various directions. The first Arabic translation was made about the year 683, by Maserjawaihus, a native of Syria; but the most eminent in this labour was Honain, called, by way of eminence, "the translator," a Christian, born at Hira in 764. Towards the end of the eighth century, a college was founded at Bagdat by the Caliph Almanzor; and there medicine obtained a permanent footing, under the fostering care of the far-famed Caliph Haroun al Raschid. Public hospitals and laboratories were founded by him for the benefit of students, who are said to have amounted at one time to no fewer than six thousand, consisting chiefly of Christians banished on account of their religion; and the Caliph Almamon surpassed even his predecessors in munificent patronage, extended to every department of art and science, and in unwearied exertions to restore and propagate the various branches of learning. By supplication he prevailed upon the Grecian emperors to send him many works in philosophy; and, employing the best interpreters that he could find, ordered all these books to be translated, and encouraged the industrious study of them by his own personal example. The medical school at Jondisabour, the

Actuarius.

Arabia.
A.D. 640.Alexander,
A. D. 527-
565.Paulus
Ægineta,
seventh
century.

¹ Mr Francis Adams, a very erudite surgeon practising in the vicinity of Aberdeen, has published the first volume of "The Medical Works of Paulus Ægineta, the Greek Physician, translated into English: with a copious commentary, containing a comprehensive view of the knowledge possessed by the Greeks, Romans, and Arabians, on all subjects connected with medicine and surgery." Lond. 1834, 8vo.

² Le Clerc, *Histoire de la Médecine*. Geneve, 1696, 8vo. Amst. 1723, 4to. Freind's *History of Physick*, from the time of Galen to the beginning of the sixteenth century. Lond. 1725-6, 2 vols. 8vo. Le Clerc only continues the history till the age of Galen. The literary history of the Greek physicians may be sought in the *Bibliotheca Græca* of Fabricius.

Surgery. capital of Chorassan, established by Sapore the First as early as the end of the third century, had by this time risen to great celebrity; and from it Rhazes, Hally Abbas, and Avicenna derived their medical education. Mesue lived during the caliphate of Haroun al Raschid, in the end of the eighth century, and Serapion during that of Almamon, about a century later; both eminent medical men in their time, but both pure physicians. The first Arabian worthy in the surgical department was the celebrated Rhazes, who presided over an hospital at Bagdat in the end of the ninth and beginning of the tenth centuries. His works are not remarkable for anatomical knowledge, which is not surprising, since the study of anatomy was strictly forbidden by the Mahomedan religion, and consequently the Arabians had to rest contented with the writings of the Greeks on that subject. "One of their religious prejudices against dissection was, that the soul did not instantly forsake the body, but lingered in some particular portion of it for some time after apparent dissolution, so that the dismemberment of it might be a species of hideous martyrdom;" a very sufficient reason why a professor of such a belief should strenuously object to the anatomization of himself and his friends. Rhazes is the first who has described spina ventosa and spina bifida. Of the real nature of the latter, however, he does not seem to have had any clear idea. Regarding cancer, he advised that the knife should never be used except when the disease was limited, and the whole tumour could be completely removed; condemning the opposite procedure as cruel and unavailing; an opinion which after-experience has shown to be most just and true. In bites from rabid animals, he first cauterized the wounds, and then prescribed emetics to expel the "black bile;" an evacuation considered most essential to the cure. His account of hernia is better than any to be found in the Greek writers. His works on surgery, however, are little more than compilations from Hippocrates, Oribasius, Aëtius, and Paulus. His confidence in oculism does not seem to have been great; for, having in his old age become blind from cataract, he could not, though urged, be prevailed upon to undergo an operation for its removal. In his time lithotomy, and some other operations, seem to have been entirely in the hands of juggling impostors. Hally Abbas, surnamed the Magician, on account of the extent of his knowledge and acquirements, lived in the end of the tenth century. **A.D. 980.** His great work, the *Al-meleky*, written about the year 980, is, in its anatomical and physiological department, a mere transcript from the Greeks; and his surgery possesses but few peculiarities. "From the idea that caustics were efficacious when a redundancy of the humours flowed to a particular part, he recommended their application for the cure of hydrocele. In the management of dropsical affections his attention was always directed to the remote causes; and he preferred puncturing in the linea alba, a little below the umbilicus, for the relief of ascites." Avicenna, who divides with Rhazes the honour of having first introduced chemistry into physic, flourished later than the two preceding Arabians. He was termed, in his day, the Prince of Physicians, and seems to have been regarded as almost miraculous for the extent and variety of his knowledge. **A.D. 980-1036.** He was born in 980, and died in 1036, without a rival, either in the medical profession, or in general science. In his great medical work, the *Canon*, the surgical department is not altogether forgotten, but holds a second place to physic; indeed, before the appearance of Albucasis, surgery seems to have been all but extinct amongst the Arabians. He has distinguished between closure of the pupil and cataract, and in operating for the latter recommends depression; extraction he considers a very dangerous experiment. It is probable that to him we owe the first use of the flexible catheter. His works are said to have remained the oracles of medical knowledge for nearly six hundred years.

Albucasis, who died in 1122, exerted himself more than his predecessors in behalf of surgery, which, by his own account, he found in a most deplorable condition; and he is chiefly distinguished as a surgical writer. Cauteries and caustics seem to have been his favourite remedies; and he becomes enraptured when speaking of the "divine and secret virtues" of fire surgically employed. The actual cautery he looked upon with veneration, and describes more than fifty affections in which his experience had found it beneficial. He is minute in his directions for its application, and forbids its use, "except by persons acquainted with the anatomy of the frame, and the position of the *nerves, tendons, veins, and arteries*;" from which latter circumstance some idea may be formed of the extent to which he himself was in the habit of roasting his unfortunate patients. He checked arterial hæmorrhage by his favourite method of cauterization, but also employed styptics, as well as complete division of the vessel, and ligature. He is supposed to have been the first to remark, that it is by the formation of a coagulum in the orifice of an artery that its calibre is closed and hæmorrhage arrested. He has described a particular instrument of his own for the cure of fistula lachrymalis, and the needle used by the surgeons of Irak for cataract. He speaks of operating for the relief of hydrocephalus, but the success of the practice does not seem to have been greater then than in its revival in our own time; for he confesses that he knew of but one successful case, and therefore does not recommend the operation. He seems to have been conversant with the mode of removing tumours by ligature when the knife is inexpedient; he advises amputation in gangrene of the extremities; and is the first who has described the mode of extracting calculus by incision in the female. His method of lithotomy resembled that practised by Paulus Aegineta; and, like him, he seems to have been bold in puncturing and excising the tonsils, removing the uvula when obstinately relaxed, and extracting polypous tumours from the fauces. He mentions bronchocele as occurring most frequently among women; but, fond of the knife and cautery as he was, he does not seem to have employed either for the removal of that tumour; indeed he tells us of "an ignorant operator who," in attempting extirpation of a bronchocele, "by wounding the arteries of the neck, killed the patient upon the spot." He invented the probang, for dislodging foreign bodies from the gullet; and in wounds of the intestines practised union of the divided parts by suture more than once with success. Though thus bold in his operations, and, like all the Arabians, too fond of the employment of instruments, he was not however without judgment and caution. For example, he condemns tracheotomy as worse than useless when the inflammatory affection of the windpipe is acute, and has extended to the bronchi; an opinion which is acknowledged as true, though unfortunately not always followed in the present day. And he exceeds even Rhazes in his dislike to operative interference with cancerous tumours, declaring that he never either cured, or saw cured, a single instance of that disease; a conclusion too nearly consistent with the history of that most implacable malady in all succeeding ages. His remarks on abscesses are most judicious; directing particular attention to their situation, and recommending their being early opened, whether "matured" or not, when in the neighbourhood of joints or other important parts, which would be injured by their continuance; a rule of practice which, if more faithfully followed, would materially diminish the number of diseased joints and bones. He also advised what has since been so much insisted on by Mr Abernethy, that when the abscess is very large, its contents should be evacuated by degrees. He is the only one among the ancient writers on surgery who has described the instruments used in each particular operation. Avenzoar, a Spanish Arab, practised physic with distinction, about the beginning

Surgery.
Albucasis,
A.D. 1122.

Avenzoar.

Surgery. of the twelfth century, at Seville in Andalusia. He describes inflammation and abscess of the mediastinum, from which he had himself suffered; and mentions a case of abscess of the kidney, from which fourteen pints of matter were evacuated. He speaks of bronchotomy as expedient in dangerous cases of inflammation of the tonsils: and in stricture of the gullet proposes three modes of treatment; the occasional passage of a tin or silver tube; the use of a milk bath, that nutritious particles may be taken up by the pores on the skin; and the injection of nutritious fluids by the rectum. He also details cases of "rupture, fracture of the hip-bone, wounds of the arteries and veins, tumours, and other varieties of surgical disease, which he appears to have understood well, and treated with discretion." He does not complain, like Rhazes, that lithotomy was in the hands of mountebanks, but tells us that the Arabians then reckoned such operations "filthy and abominable, and unfit for any man of character to perform;" and held that "no religious man, according to the law, ought so much as to view the genitals." The brightest name in the history of Arabian philosophy is that of Averrhoes, the pupil of Avenzoar, born at Cordova about the middle of the twelfth century, and said to have died in the year 1206. But he cultivated the study of medicine only as a branch of general philosophy, and surgery he seems to have altogether neglected.

Averrhoes,
A. D. 1206.

Such were the Arabians. Of these, Albucasis was the most famous in surgery, as Celsus had been among the Romans, and Paulus Ægineta among the Greeks. But even he could not escape the unfortunate failing of the Saracenic school; endless invention of manifold and complicated instruments, attaching far too much importance to the mechanical part of their profession, and mistaking the inspiration of terror and infliction of cruelty for energetic and judicious surgery. In order, for example, to arrest hæmorrhage from a wounded surface, if time pressed and assistants were scarce, it was not uncommon to dip the part into boiling pitch, a liquid which was then dignified with the appellation of a styptic. They however systematically divided physic, surgery, and pharmacy into three distinct professions; and so, by commencing the division of labour, may be considered as having done something not unimportant towards the ultimate advancement of medical knowledge. "The last traces of their intellectual illumination appeared among the Spanish Moors in the thirteenth century, when the Christian arms having become more and more powerful, they were compelled to substitute the field for the study—the sword for the pen—and, before an overwhelming opposition, were at length driven from a region whose fields they had tilled, and whose olives they had gathered, for a thousand years. With the decline of the Saracenic school, the daylight of science went down over the nations; and an intellectual darkness, which endured for three hundred years, enveloped the general face of society. All the fountains of science were dried up, and the world seemed retrograding into the unilluminated chaos of ignorance."¹

School of
Salerno.

A knowledge of the Greek and Arabian systems of medicine was introduced into Italy, at Salerno, in the begin-

ning of the eleventh century; and this school soon rose to celebrity as a seat of medical learning. In the time of the Crusades, Salerno was a place of great resort for warriors of all nations passing between Europe and Palestine; and by these wanderers, on their return, the light of medical science was thence slowly conveyed over Europe. It obtained the privileges of a university; but the medical school of Salerno did not long retain its high reputation. In modern times, it is chiefly remembered on account of the *Regimen Sanitatis Salernitanum*, a singular production, of which more than one hundred and sixty editions are known to have been published. Though written in the name of the *Schola Salernitana*, it has generally been ascribed to Joannes de Milano. The English king to whom it is addressed is supposed to have been Robert of Normandy, whose claims to the English crown were recognised by some of his contemporaries. The poem opens with these lines:

Anglorum Regi scripsit Schola tota Salerni.
Si vis incolumem, si vis te reddere sanum,
Curas tolle graves, irasci crede profanum,
Parce mero, cœnato parum, non sit tibi vanum
Surgere post epulas, somnum fuge meridianum,
Non mictum retine, nec comprime fortiter anum.²

In the twelfth century, the Jews practised medicine, not only among their own tribes, but also among the Moors and Christians; and though, like all others of this age, merely treading in the beaten track of the Greeks and Arabians, yet, from their superiority in such learning, they came to be reputed the most skilful practitioners. About the middle of that century, as has already been stated, surgery was completely separated from physic, by the edict of the Council of Tours prohibiting the clergy,³ who then shared with the Jews the practice of the healing art in Christian Europe, from in any way causing the effusion of blood, at least as a means of curing bodily ailment. Surgery was in consequence abandoned to the uneducated laity, and sunk to a deplorable state of prostration; it became a mere matter of plasters and unguents; and if any thing happened to be written on the subject, it was but a bad compilation from the Arabians.⁴ We shall however notice some of the more remarkable events in connection with it during its temporary abasement. In the year 1271, the foundation of the College of Surgeons at Paris was laid by Pitard, a surgeon of eminence in those days, and whose enthusiasm effected something towards raising his humbled profession. About the same time lived Gulielmus de Saliceto, a professor at Verona, said to have been "a powerful man" in both surgery and medicine. He seems to have earnestly dissuaded men from the copying and study of books in preference to practical experience, and he himself set a better example. In our own country Gilbertus Anglicanus is the first name connected with surgery; but he seems to have been little more than a compiler from the Arabians. He lived about the beginning of the fourteenth century; and shortly after him appeared John of Gaddesden, author of the *Rosa Anglica*, and said to have been an erudite and ingenious man, as well as a skilful practi-

A. D. 1271.

Fourteenth
century.

¹ Moir's Outlines of the Ancient History of Medicine. Edinb. 1831, 16to. Of this work we have not scrupled to make free use in the course of the preceding observations.

² *Regimen Sanitatis Salernitanum*: a Poem on the Preservation of Health, in rhyming Latin verse, addressed by the School of Salerno to Robert of Normandy, son of William the Conqueror, with an ancient translation; and an introduction and notes by Sir Alexander Croke, D.C.L. and F.A.S. Oxford, 1830, 12mo.

³ The early clergy claimed the practice of medicine as their peculiar privilege, and, using it chiefly as a means of personal power and gain, disgraced it by ignorance, charlatanry, and imposture. It was to check this that the Roman council assembled by Pope Innocent II. in 1139, threatened with the severest penalties those monks and canons who applied to the practice of medicine, "neglecting the sacred objects of their own profession, and holding out the delusive hope of health in exchange for ungodly lucre." But even this, though followed by the more peremptory edict at Tours in 1163, where Alexander III. presided, did not make them altogether forego what they found so convenient and profitable. It was necessary to repeat the edict in 1179 and 1216; but notwithstanding, the monks continued still to practise physic, and it was chiefly by their evil influence that the school of Salerno was brought to decay.

⁴ The writers of that age were aptly termed by Severinus, Arabistæ.

Surgery. tioner. About the middle of the fourteenth century, Guy de Chauliac practised with renown at Avignon, and is "accounted one of the revivers of the languishing art." In his *Chirurgia*, a history of the state of surgery in his day,¹ we find the first mention of the Cæsarean operation. Contemporary with him was John of Ardern, an English surgeon. He wrote with simplicity and honesty, and may be regarded as a reviver of surgery in that country. In his practice he was peculiarly successful in the treatment of fistula in ano, and thereby acquired a great reputation. Valesco de Taranta, a Portuguese, practised at Montpellier, and wrote on surgery in the beginning of the fifteenth century. He was the first who proposed the cure of cancer by the application of arsenic. About the middle of the same century, lithotomy, the practice of which had hitherto been confined to itinerant and ill-informed operators, was restored to the regular profession by Germain Colot, a French surgeon, high in favour with Louis the Eleventh. He first contrived to witness the operation by the itinerants, then practised it on the dead body, and at last performed it successfully on a condemned criminal who happened to be afflicted with stone, and who consented to undergo the operation on condition of being pardoned if he survived. His success, in having thus doubly saved life, obtained for Colot much renown; and lithotomy ever after continued a regular part of surgical practice.² The fifteenth century contains other two events important to surgery; the discovery of the art of printing, about the year 1450, which gave a new impulse to science and literature, by rendering the accumulated stores of knowledge more accessible; and the importation of the venereal disease from America, by the first discoverers of that continent, giving the *small* pox as if in exchange, about the year 1492.³ In this century also the Turks captured Constantinople, thus overthrowing the last remains of the eastern empire; and by the multitude of Christians who fled from that city many manuscripts of the Greek medical writers were brought to Italy, and their contents thence slowly disseminated over Europe.

Hitherto surgery can scarcely lay claim to an actual revival. Occasional attempts had been made to raise it from its low position, but all proved abortive. At length, however, in the beginning of the sixteenth century, the practitioners of the healing art were happily convinced that the observation of nature was superior to compilation from the ancients, whether Arabian, Roman, or Greek; they consequently ceased to tread blindly and servilely in the footsteps of their predecessors, and a new era arose to the profession. About the same time Vesalius gave birth to anatomy, properly so called;⁴ illuminated by which science, surgery became a worthy object of pursuit to men of talents and education, and under their cultivation it was gradually raised to an enlightened and liberal profession.

The most conspicuous name in this new era of surgery is that of Ambrose Paré, a Frenchman. In this country surgery was then sadly depressed, having retrograded since the time of John of Ardern. Its list of practitioners comprised barbers, farriers, sow-gelders, cobblers, and tinkers; and it is not matter of surprise that from among these no name has been handed down as worthy of remembrance. The combination of the practice of surgery with the more harmless manipulations of the barber, was not confined however to this island, but existed also in France, and continued in both countries for upwards of 200 years. The great Paré does not reject the appellation of barber-surgeon, as applied to himself; nor does he seem to think that there is any thing derogatory in the title. He was surgeon successively to Henry the Second, Francis the Second, Charles the Ninth, and Henry the Third, of France; and followed the French armies in all their campaigns down to the battle of Moncontour in 1569. His consequent experience of gunshot and other wounds, on the field of battle, naturally directed his attention to the subject of hæmorrhage; and it is to him that we owe the revival and improvement of the method of arresting bleeding from arteries by ligature, and discontinuance of the cauteries and styptics, which, to the disgrace of surgery, had hitherto been in exclusive use for this purpose. Yet so averse are mankind to abandon their ancient customs, that the improvement of Paré was not sanctioned till after much abuse and persecution, directed both against himself and his discovery; indeed so bitter and unrelenting were his jealous brethren, that he was compelled for his own safety to adduce garbled and incorrect extracts from Galen and other ancients, in proof that to them, and not to him, the invention was to be referred. So far he was less in error than he himself supposed, for we have already stated that he has merely the merit of reviving the use of the ligature.⁵ Celsus distinctly advises its employment when pressure fails to stop arterial hæmorrhage; and Albucasis sometimes condescended to use it instead of his favourite cautery and cruel styptics. Paré, however, was amply repaid by future fame for the opposition which he had at first sustained. He rose to an unparalleled height of popularity with the army, by whom he was absolutely adored. On one occasion, his mere presence among the garrison of a beleagured city about to capitulate, re-animated the troops to such an extent, that their resistance became more energetic than before, and the besieging army perished beneath the walls. By his sovereigns he was also highly esteemed. From the general massacre on the fearful night of St Bartholomew he was rescued by the personal exertions of Charles the Ninth, his great merits being appreciated even by that weak and cruel monarch. But he was not content with the respect and praise of his contemporaries; his writings, the result of great experience and accurate observation, freed from the

¹ Some idea may be formed of the languishing state of surgery at this time, from his division of the surgeons into the following five sects. The first applied cataplasms indiscriminately to every description of ulcer and wound. The second in similar cases employed wine only. The third used emollient ointments and plasters. The fourth, chiefly military surgeons, promiscuously employed oils, wool, potions, and charms. The fifth, "consisting of ignorant practitioners and silly women, had recourse upon all occasions to the saints, praised each other's writings perpetually, and followed each other in one undeviating track, like cranes."

² In the beginning of the sixteenth century, cutting upon the staff was introduced by Johannes de Romanis and Marianus Sanctus, and very successfully followed by Laurence Colot, a descendant of Germain.

³ The first author who clearly describes the venereal disease is Marcellus Cumanus, who wrote in 1495. It was not till 1530 that Fracastorius wrote his celebrated poem *De Morbo Gallico*, in reference to which it has been said that the chaste and classic elegance of its language was worthy of the best days of imperial Rome, and the mellifluousness of its versification hardly surpassed by the bard of Mantua himself. By G. Torella, physician to Pope Alexander the Sixth, we are informed that the insane abuse of mercury as a means of cure was not quite a universal practice on the outbreak of the disease; for, in describing some particular forms of mercurial ointment, he himself states that "they destroyed an infinite number of people, who in this case did not die, but were downright killed; and these bold empirics must give an account, if not in this, in the next world, of their practice, and be drowned in the pit of repentance." It is but very lately that the "pit of repentance" ceased to be useful under very similar circumstances.

⁴ A little later in the century, Fallopius taught anatomy at Pisa, and Eustachius at Rome, and to their efforts, as well as to those of Vesalius, the advancement of that science is much indebted. Fallopius died in 1563; Eustachius in 1574.

⁵ As an example of how little the hint of Celsus was attended to, we may mention, that Procopius relates how Artabazes perished of a wound in the neck, "the artery of the neck having been cut through, so that the blood could not be stopped." Their cauteries and styptics had no effect on the carotid, or its larger trunks.

Surgery. yoke of authority, and digested by genius of a high order, have rendered him immortal. His works, first published in 1535, and afterwards more fully in 1582, exerted a most powerful and beneficial influence upon his profession. The influence was not however immediate; for at his death the light he had shed was for a time obscured, surgery reverting to the state of degradation in which he found it, in consequence of its baneful association with barberism. Pigrai was his successor, but an unworthy one: endeavouring to follow the footsteps of his master, he obscured and almost effaced them. The most interesting of Paré's surgical treatises is that on gunshot wounds, a class of injuries then of recent introduction, and little understood: the murderous cannon and firelock had not long been in use.

Seventeenth century.
C. Magatus.
Tagliacotius.
Severinus.
F. Aquapendente.
Wiseman.
Harvey.
A. D. 1628.
Young.
F. Hildanus.
Scultetus.
Purmann.
Heister.

In the seventeenth century surgery again revived, resuming the impulse which the genius of Paré had imparted. Italy produced Cæsar Magatus, who simplified, and consequently must have improved, the treatment of wounds; the never-to-be-forgotten Tagliacotius, with his rude repairs of the human face; and Marcus Aurelius Severinus, a skilful and intrepid operator. At the end of the sixteenth and beginning of the seventeenth centuries, Padua was favoured with Fabricius ab Aquapendente, the preceptor of Harvey, a most distinguished physiologist, and the most eminent surgeon of his time. His *Opera Chirurgica* passed through no less than seventeen editions, and contain not only an excellent digest of surgery as it then was, but also many improvements of his own. About the middle of the seventeenth century arose the true father of British surgery, our own Wiseman, the Paré of England. One or two English names are to be found before him: William Clowes, a military surgeon of some eminence, attended the Earl of Leicester's army in the Low Countries, and wrote on gunshot wounds; and Lowe, a Scotchman, gave to the world a Discourse on the whole Art of Chirurgery, dated 1612: but Wiseman doubtless is the first Briton worthy of note in surgery. He was serjeant-surgeon to Charles II., and amidst the horrors of the civil wars had ample scope for the study of his profession. His surgical works, consisting of eight treatises, dated 1676, contain much information, at that time most valuable, and still amply rewarding an attentive perusal. In military practice he strongly advocated immediate amputation, "while the patient is free of fever," in the case of such injuries as rendered preservation of the member improbable, of course allowing the primary shock of the accident to be past; a point of practice which long discussion in after years served to confirm. It was not till his time that surgeons ceased to believe that gunshot wounds were necessarily envenomed by the powder and ball, and had to be treated accordingly with potent and cruel dressings. The immortal Harvey, contemporary with Wiseman, cannot perhaps be classed among the eminent surgeons, having principally confined himself to anatomy and physiology, yet he is inseparably connected with that science by his discovery of the circulation of the blood; a discovery which has done so much for the advancement of all medical knowledge, but of surgery in particular. James Young, a surgeon in Plymouth, may be said to have been also contemporary with Wiseman, having written in 1679. He is the first who proposed amputation by a flap, an improvement to which two French surgeons, Verduin and Sabaurin, lay claim; and he is also the first who recommends limited compression of the main artery in amputation.

Surgery. versity of Helmstädt, wrote a system of surgery, which has been translated into most of the European languages, and is still in high repute.

Holland likewise possessed successful practitioners of surgery, but tainted with an unworthy concealment of their methods of cure. Rau, a native of Germany, though a professor at Leyden, was perhaps the most successful lithotomist that ever lived, but he kept his method of operating a profound secret, and made it a mystery even to his own pupils; as appears from the circumstance that his two favourites, Heister and Albinus, of a more liberal spirit than their master, in attempting to divulge his secret for the benefit of the profession at large, have varied most materially in their statements. This illiberal spirit pervaded the other branches of medicine as well as the surgical. The famous anatomist Ruysch preserved inviolate the secret of his wonderfully minute injections, although really the discovery of his friend De Graaf; and Roonhuysen the accoucheur worked stealthily with his invented lever. The succeeding generation however removed this stigma from the Dutch; and their great Camper was equally celebrated for the number of his discoveries and the zeal with which he made them known.

From the time of Paré, France produced no surgeons of great eminence until the eighteenth century. In the seventeenth, we find the names of Dionis, Belloste, Saviard, and a few others of some renown, but not at all equal to their contemporaries in other nations. Some idea may be formed of the then feeble condition of surgery in France, from the fact, that Louis XIV. was not cured of a simple fistula in ano, until after his life had been in no small degree endangered by repeated abortive operations. That the French can boast of surgeons of the first class in the next century, however, is indisputably shown by the simple mention of Petit and Desault; names that must ever occupy a proud place in the annals of surgery. The former, adding to the most powerful talents great industry, and an innate love of his pursuits, rose rapidly to eminence, though not without much envious opposition, which seems to be the portion of nearly all those who occupy a pre-eminent place in the profession. On general surgery, he has left a work of much value; and his treatise on diseases of the bones, though produced at an early age, entitles him to be called the father of that branch of pathology. For many years it remained the best work on the subject. He was the inventor of the screw-tourniquet, and the first who operated for fistula lachrymalis by transfixion of the sac. He contributed largely to the Memoirs of the Royal Academy of Surgery; an institution which has done much for the advancement of surgery, not only in France, but throughout the world. Its Memoirs, containing the result of the labours of many eminent men, constitute a work of the greatest value. Desault, also of high reputation, both as an anatomist and as a surgeon, was the first who taught surgical anatomy, and gave clinical lectures on surgery. His improvements on the apparatus for fractures were most important; and a splint invented by him is still in use for fractures high in the femur. His modifications of cutting instruments were also good; among others, changing the amputating instrument to a straight knife, instead of the old curved weapon. He was the first who contemplated the cure of artificial anus, resulting from strangulated hernia; and he further improved Paré's revival of ligature of the arteries. The proposal of curing aneurism by ligature of the vessel on the distal side of the tumour originated with him; a proceeding, however, of which the merit is still dubious. His writings are both valuable and extensive. After the great names of Petit and Desault, not a few French surgeons of the same century, though less eminent, yet deserve mention; Le Dran, a copious and excellent author; Le Dran, Sabatier, famous in the department of operative surgery; &c.

Surgery. Garengot, Louis, La Motte, Frère St Cosme,¹ Portal, Pouteau, Lecat, Chopart, Morand, Moreau, &c.

America. It is about the middle of the eighteenth century that our attention is first attracted to our transatlantic brethren. In 1763, lectures on anatomy and surgery were delivered in Philadelphia by Dr Shippen; and in 1791 the medical school of that city was completely established, under Benjamin Rush, the Hippocrates of Colombia; a school which has since lent invaluable aid to the progress of both medicine and surgery.

Pott. Our own country was at this time by no means barren in surgery. Percival Pott and John Hunter are names which occur, the one in the middle, the other in the end, of the eighteenth century, and are fully equivalent to Petit and Desault; indeed Hunter may be justly ranked as the greatest man that ever graced the profession. Pott, the best author, operator, and practical surgeon of his time, greatly improved the practice of surgery in England, both by his writings and by personal example. Like Desault, his attention was particularly directed to the treatment of fractures, of which he had some painful experience in his own person, having sustained a severe compound fracture of the leg. He has left a justly celebrated treatise on the subject. On amputation his observations are most important, clearly discriminating between those cases, of injury more particularly, which demand the operation, and those which do not; at the same time marking the period most advantageous to its performance. Regarding injuries of the head, he wrote with more precision, and at the same time with more originality, than any previous author, and will ever remain a valued authority upon that subject. The same may be said of his description of vertebral disease, he having been the first who clearly distinguished between those curvatures of the spine depending on mere change of form in the bones, and those occasioned by caries or abscess: the latter formidable affection is still known as "Pott's disease" of the vertebræ. He greatly improved the treatment of fistula in ano, and abscesses in general; and by simplifying the whole art of surgery, discarding the cautery and escharotic unguents, or rather limiting them to their proper place and use, employing also the cutting instruments with caution and reserve, and placing more implicit trust in, and showing more respect for, the powers of nature than had hitherto been the custom, he achieved a most important and beneficial reform in surgery. Until his time, the maxim "*Dolor medicina doloris*" remained unrefuted. The actual cautery, for example, was in such general use, that "at the time when surgeons visited the hospital, it was regularly heated and prepared in the wards, and in the presence of the patients, as a part of the necessary apparatus. Mr Pott lived to see these remains of barbarism set aside, and a more humane and rational plan, of which he was the originator, universally adopted." John Hunter, a native of Scotland, the pupil, first of Cheselden, and afterwards of Pott, though not remarkably distinguished as an operator, was the most gifted surgeon of which the medical profession can boast, and no less eminent as an anatomist, physiologist, and general philosopher. His researches comprehended a wider range than those of Pott, but arrived at the same end, the improvement of surgery. The knowledge obtained by his vast inquiries into physiology, pathology, and human and comparative anatomy, was, with all the power of his genius, brought to bear upon the practice of

the profession, and with the happiest success. The doctrines of adhesion, granulation, ulceration, and inflammation with its various results, were, until detected and explained by him, comparatively obscure and uncertain; and no one is ignorant how much the successful treatment of disease, either by surgery or medicine, must ever depend on an accurate and familiar knowledge of these rudiments. To him we are indebted for the simplification of more than one operation, the discovery of the vitality of the blood, important advice as to the treatment of gunshot wounds, the enforcement of excision of bitten or poisoned parts, many new facts as to the physiology and pathology of teeth, and other valuable additions to practical surgery. But these assume an unimportant place among his deeds, when placed beside the two with which his name is indelibly associated—the cure of popliteal aneurism by ligature of the femoral artery, and the elucidation of the venereal disease; his work on the latter subject still remaining standard, and in many respects unsurpassed. His improvement of the operation for aneurism marks an era in the history of surgery, being one of the most important of its advances. Dissatisfied with the cruel, formidable, and unsatisfactory operation for popliteal aneurism, by incision of the tumour and ligature of the vessel at its diseased part, he made himself aware of the causes of failure by the old system, contemplated the plan of cure which bears his name, satisfied himself of its practicability by diligent study and experiment, successfully brought it to the test of actual practice; and then, extending the principle to all aneurisms, effected for surgery a great triumph over that formidable disease.² His first operation was performed in 1785, and was successful; proving that permanent removal of the force of the circulation in the aneurism is sufficient for its cure, by permitting consolidation and ultimate obliteration of the tumour. Since his time the method of applying the ligature has been considerably improved, and the certainty of success consequently increased. But "the more brilliant a discovery, and the more beneficial its results, the more certain is its author of becoming the butt of envy and the object of detraction." And accordingly we find that Hunter has not been permitted to remain in undisturbed possession of his discovery. Its merit has by some been claimed as due to Aëtius; others, with better hopes of success, support the pretensions of Guillemeau (a pupil of Ambrose Paré), Anel,³ and Desault; but a candid inquiry into facts and dates will ever result in ascribing the honour to our illustrious countryman. Had he even been deprived of this, his name must still have been immortalized by other and more palpable labour of his mind and hand—his books and museum.

In the same century with Pott and Hunter, Britain also produced White, an excellent practical surgeon and lucid writer; Cheselden and Douglas, two eminent lithotomists, the former peculiarly successful; Sharp, famed for his *Critical Inquiry into the State of Surgery*; and Monro, a name indissolubly united with the birth and fame of the Edinburgh medical school.⁴

In Italy, where, during the times of Pott and Hunter, several eminent surgeons lived, Lancisi, Morgagni, Bertrandi, Troja, &c.,—the labours of Hunter in aneurism were ably followed up by Scarpa, who still further elucidated the doctrines regarding the new treatment of that disease, and established the success of the operation. He was also eminently successful in his researches as to the anatomy and patho-

¹ Frère Jean de St Cosme, although a monk, had been educated as a surgeon. He was the inventor of the Lithotome Caché, and with it obtained wonderful success and celebrity as a lithotomist.

² "So discouraging were the results of the old operation, that many surgeons preferred performing amputation of the aneurismal limb."

³ Guillemeau and Anel placed their incisions and ligatures in the immediate neighbourhood of the tumour.

⁴ Dr Monro was appointed professor of anatomy to the company of surgeons in 1719, and during the ensuing year he was appointed to a similar chair in the university. Several other professors in the same faculty had previously been nominated; Sir Robert Sibbald, Dr Halket, and Dr Pitcairne, so early as the year 1685. But Dr Monro was the first who regularly delivered public courses of lectures, and he may in a great measure be regarded as the founder of the medical school of Edinburgh.

Surgery. logy of hernia, a subject which he has made peculiarly his own. The same century saw in Germany, Schmucker, **Haller.** Richter, and the great Haller, whose *Disputationes Chirurgicæ* bear, equally with his other works, the impress of both labour and genius of a high order.

Nineteenth century. The nineteenth century will not yield to any former era in a numerous and bright array of names dear to surgery. **Abernethy, &c.** It has seen the fall of Abernethy and Dupuytren, brilliant stars in the galaxy, and mourns others highly valued; but vast and powerful is the host who are still labouring, with distinguished success, in their noble calling. In all civilized countries, the dark days of the profession have, we trust, for ever passed away; and many are the illustrious names in which it now exults, more particularly in France and Germany. But we hesitate not to assert,—and we cannot think that national prejudice exerts any influence in leading us to the conclusion,—that no country can boast of such a crowd as that by which Britain, in the present century, has been and still is adorned. And we feel an honest pride in stating, that the medical school of Edinburgh can claim connection with not the least among these living names.

Modern surgery. Having followed surgery thus far, from the earliest times, in its most notable points of history, we shall proceed to inquire briefly into the practice of the present day. And, **Operations.** first, of the art of operating. It is a favourite phrase by which operations are stigmatized as the “opprobria of surgery.” Nothing can be more unjust. So long as injury and disease are permitted to afflict mankind; so long as bones are crushed, and flesh bruised and torn; so long as tumours grow, and gangrenes spread—and we know nothing short of direct divine interposition that can wholly prevent such accidents—it is only by operation, dexterously executed and skilfully timed, that the human frame can be kept in repair, and life prolonged. To be able safely and expeditiously to remove parts which accident has rendered totally useless, and which would prove highly injurious if longer attached to the body; to take away diseased formations, or other noxious substances, and, at the expense of but brief suffering, to dispel torture which had rendered existence a burden for previous weeks, months, and years; to accomplish such results, though it be by blood and pain, is alike creditable to the operator and beneficial to the sufferer. It is not a disgrace to the profession that certain injuries and diseases are of so grievous a nature as to be incurable but by operation, for such is the dispensation of Providence; it is the surgeon’s boast to have recourse to the knife as seldom as possible; but it is also his pride to be able by it, as a last, and, to both parties, painful resource, to ward off suffering, deformity, and death. It is not, to operate, but to operate unseasonably, unnecessarily, unskilfully, that can ever bring disgrace; and to refrain from performing an operation when it is loudly and plainly called for, would carry not only opprobrium to surgery, but guilt and shame to the surgeon. We are speaking of surgery as it now is, not as it was. In former times operations were its disgrace. Knives, hot irons, screws, files, and saws, were employed with cruel and ignorant recklessness; but of late years, it has been the object of each truly good surgeon to simplify and diminish the number of instruments, and at the same time to use them as seldom as possible. He does not hesitate to employ them when his knowledge and experience tell him they have become indispensable. On the contrary, he will probably be urgent in their application, knowing that an early wound may save much after-suffering; but, in the first place, he will exert all his skill and all his powers, by

Surgery. milder measures to counteract injury and restrain disease, so as to supersede the necessity of operating. To effect this is doubtless the true triumph of his profession; and this triumph he often attains. But he must be Utopian indeed who can seriously hope that the period will ever arrive when operations shall have altogether ceased to be required. In the progress of surgery, many a murderous weapon, at one time in frequent use, has grown thick with rust, and become almost unknown; those retained are few, effective, and never employed without good cause. The growth of science and experience is bringing the ravages of disease more and more under control; operations are not only less frequent, but more simple and less dangerous in the performance; and it is the pride of the modern surgeon to witness and promote this great improvement of his profession. But there are, and ever must be, diseases which we cannot expect to cure, and injuries against which we cannot hope to strive successfully, so as to preserve life, by any measure short of operation. Modern surgery, accordingly, while anxious to limit the necessities for operation, is not the less aware of its importance as a means of cure; and has not only directed attention towards its improvement, but also extended its application, and with the happiest result, to diseases formerly unopposed. Many patients, for example, are now by the knife freed from morbid growths and natural deficiencies, who were formerly left an unprotected prey to deformity and disease.

The necessity for an operation having been clearly established, our object then is to perform it as safely and expeditiously as possible. We now no longer hear, as we did even so lately as fifteen or twenty years ago, of a poor patient being tortured for the space of an hour, by cruelties misnamed lithotomy: in a few minutes the bladder is cleared of extraneous matter; and almost the like number of seconds will suffice for amputation.¹ With this celerity, the safety of the patient is not only equally, but more secure; for rapidity is still held subservient to, though conjoined with, excellence of performance; and the mere absence of protracted pain confers a most important advantage on the reparative powers of the system. A prominent cause of this improvement in the art of operating, is an increased simplicity of the instruments, their arrangement, and use. On this subject, one who is *facile princeps* among the operators of the present day,² observes: Our armamentaria should contain simple and efficient instruments only; the springs, grooves, notches, and curves, seeming to be chiefly intended to compensate for want of tact and manual dexterity. The apparatus, though simple, ought to be in good order, and should always be placed within easy and convenient reach of the operator, so that he may be in a great measure independent of the lookers-on, who, owing to anxiety or curiosity, hurry and agitation, are apt to hand any thing but what may at the instant be required. He will consider well what place he himself will most conveniently occupy during the operation; and having obtained proper assistants, he will make sure that they all understand what is expected of them. In short, before he ventures to begin, he will ascertain that every thing is arranged, and in proper order; more particularly, that the cutting instruments have good points, that their edges are keen, and that the joints of forceps and scissors move freely and readily. The principle on which the instrument is made to cut should be well considered. Every knife is to be looked upon as a fine saw; the teeth of some are set forwards, and these cut best from point to heel, as does a razor; but the greater number are set in the opposite direction,—for example, the com-

¹ Nor are there many now, who, alluding to their operative powers, would be likely to express themselves as did the preceptor of the immortal Harvey, first surgeon of his time though he was: “If it be a moveable tumour, I cut it away with a red-hot knife, that sears as it cuts; but if it be adherent to the chest, I cut it without bleeding, with a wooden or horn knife, soaked in aquafortis, with which, having cut the skin, I dig out the rest with my fingers!”

² Mr Liston.

Surgery. mon scalpel and bistoury,—and act efficiently only in being drawn from heel to point. The cutaneous tissues, and in many instances the subjacent parts, should be divided at once and completely, by a single incision made lightly and rapidly; for the pain experienced is in proportion to the pressure and tardiness of movement in the instrument applied. The pain of partial division of the skin, in tails left at each end of an incision, is very great; and, besides, such wounds are not so available, as they would otherwise be, for the intended purpose of evacuating fluid, for permitting the extraction of foreign bodies, or for the dissection of morbid growths. Also, the pausing of a surgeon in the midst of a dissection, and the resort to fresh and more extensive incisions of the surface, is not only always awkward, but attended with much additional and unnecessary pain to the patient. Every cutting instrument should be well balanced, and placed in a steady, smooth handle; the point should either be in a line with the back, which ought then to be perfectly straight, or both edge and back should be so far convex, the point being in the middle of the blade. The form and size of the instrument ought always to be in proportion to the extent of the proposed incisions, both as regards their length and depth: nothing can be imagined more cruel and reprehensible, for example, than an attempt to remove the lower extremity of a full-grown person with a common scalpel or dissecting knife. If an extensive incision is necessary, an instrument should be employed possessing length of edge sufficient to separate the parts smoothly and quickly. Should the operator be required to cut on important parts, to perform a delicate dissection of the living tissues, he will choose a short-bladed instrument, with a handle rather long and well rounded; and after the superficial incisions have been effected, he will hold it as he would a writing pen, lightly but firmly, so that he can turn the edge, and cut either towards or from himself, as occasion may require. A small well-made scalpel, with a good point, and less convexity than those usually employed, is the instrument best adapted for such a purpose. Grooved probes and directors should be used as little as possible. With a little practice, incisions may be made upon the most delicate parts, without risk, by the hand unsupported, one layer being cut after the other. If any instrument is wanted to make the proceeding more safe—if the closely investing fasciæ of a hernial tumour, for example, are to be cautiously raised—dissecting forceps will be found the most convenient instrument for elevation previous to incision. In dividing the skin, the knife, whether a scalpel or a bistoury, is to be held and entered with the point and blade at right angles to the surface. It is carried with a decisive movement down to the subcutaneous cellular tissue; the blade is then inclined towards the part to be divided, and by a rapid and slightly sawing motion—as little pressure being applied as possible—the division is effected to the desired extent. The incision is finished by withdrawing the knife in a position perpendicular to the surface, so as to divide the entire thickness of the skin at the extremity as well as origin of the wound. For dexterously effecting such manipulations, the “fingers must be educated;” and diligent practice in the dissecting-room will be found the best foundation for surgical dexterity, as it is for sound surgical knowledge: “it is only when we have acquired dexterity on the dead subject, that we can be justified in interfering with the living.” By practice the pupil will be enabled to use either hand almost equally well, and none should neglect to attain this power, for an ambidexterous surgeon possesses

a great advantage as an operator. An ordinary degree of expertness is within the reach of any one who will industriously seek for and improve the opportunities for its acquirement; but yet a certain combination of natural qualifications is undoubtedly necessary to the attainment of pre-eminence in operative surgery; for a great operator in one respect resembles a great poet,—“nascitur, non fit.” The importance of these natural gifts did not escape Celsus. “He must be young, or at most but middle aged,” says he, “and have a strong steady hand, never subject to tremble. He must be ambidexterous, and of a quick, clear sight. He must be bold, and so far void of pity that he may have in view only the cure of him whom he has taken in hand, and not, in compassion to cries, either make more haste than the case requires, or cut less than is necessary, but do all as if he were not moved by the shrieks of his patient.” The coolness and courage thus inculcated are the most valuable natural gifts of the surgeon; and it would be well did every patient remember that they are equally important in himself, for on his steadiness and patience under suffering much of the celerity and success of an operation depends. Expert skill in operation contributes greatly towards perfect self-possession; for the dexterous surgeon, like an adroit master of the sword, “will not enter rashly into difficulties, but being engaged from necessity or conviction, will bring himself through with courage.” He who has what is strangely termed “common sense,” enjoys another of nature’s choicest gifts; and to no possessor does it prove more valuable than to the surgeon, as by its judicious application the want of more than one of the prominent qualifications considered as essential to his success may be fully compensated.¹ But a combination of the natural essentials for an eminent operator, as may readily be imagined, falls to the lot of only a small number; and to that gifted few it were well, when circumstances will admit of it, to delegate the performance of the more dangerous and difficult operations. Every surgeon, however, should be ready to undertake the greater number of surgical proceedings without hesitation or delay; for though, as we have already stated, operations do not form the most important part of surgery, they still are, and ever must be, inseparable from its successful practice.

Hæmorrhage, the most prominent accompaniment of Hæmorrhage. surgical operation, is now in much better command, both temporarily and permanently, than it used to be, and consequently is less dreaded by the surgeon. During the operation, complicated machines, encircling the whole limb—very painful from the great and general pressure, and increasing the loss of blood by swelling the venous torrents and retarding retraction of the minor vessels—are now superseded by the skilful application of the “educated” and steady hand of an assistant, compressing the trunk of the main artery, and it alone. This change is particularly advantageous to amputation, admitting of its performance with greater despatch, less hæmorrhage, and less pain. In more tedious proceedings, the cautious extirpation of tumours, for example, the surgeon commences his incisions where he knows the principal vessels enter the part about to be the scene of operation: they are consequently divided at once; an active and steady assistant secures their orifices by the pressure of one or more fingers, and the proceedings are completed with comparatively little loss of blood, and without the hinderance of applying ligatures to any arterial branches until all the knife-work has been completed. Sometimes, when the part is unusually vas-

¹ The ancient Athenians had a law, that no slave or woman should study medicine; probably fearing want of education in the one class, and deficiency of common sense in the other. Perhaps it were well if a similar protection to the practice of the profession were in present force, as was proposed by the late Mr Alexander Wood of this city. In addition to the usual examination for the diploma of surgeon, he wished to establish a jury to determine on the common sense of the candidate, stating as his reason, “If they have not *that*, I would not give a — for the rest of their medical knowledge.”

Surgery. cular, and important vessels come from all sides, this rule cannot be followed, and ligature must be applied to each important branch as it is divided; but this necessity for delay does not often occur. The ligature,—a firm hempen thread, well waxed,—ought in all cases to be applied very carefully, and made to enclose the orifice of the artery alone, which for this purpose is pulled out by common well-pointed dissecting forceps, or, when the parts have been consolidated by infiltration, by a sharp tenaculum. A double knot, carefully secure, having been made upon the isolated orifice, one end of the ligature is cut off close to the knot, the other being left protruding from the most dependent part of the wound, that the ultimate separation of the ligature and its enclosed slough may thus be watched and made certain. It was lately recommended, and is still practised by some, to cut away both ends of the ligature close to the knot, in the belief that the union of the wound by the first intention would thus be favoured, and in the hope that the noose would become encysted in its original situation, and produce no further annoyance; that hope however has been disappointed. It was then thought, that by making the ligature of an animal substance, as catgut, it might be slowly removed by absorption, and thus be prevented from becoming a source of future irritation; but that plan also failed. No doubt, ligatures in such circumstances have long remained quiescent, but that has been seldom; sooner or later, perhaps after the cure has been thought complete, they occasion the formation of abscess after abscess, and produce much irritation, until they themselves are expelled; and thus recovery is in the end much protracted. The usual practice therefore now is, to leave one end of each ligature a little protruding from the lips of the wound, in order to secure their complete expulsion at the proper period. These remarks of course apply only to wounds which are approximated soon after infliction, with the hope of their adhesion. When the cut surface, on the contrary, is left open, in order to suppurate, both ends of each ligature should be removed close to the knot, the practice being then unexceptionable. Another innovation lately practised, was the substitution of torsion for ligature of the arterial orifice, thereby imitating the natural means of suppressing bleeding. The method has only been found to succeed well with vessels of the second class, such as those of the fore-arm—being inapplicable to the smaller twigs, and not safe in the case of the larger arterial trunks. In every extensive wound, therefore, some ligatures must be applied; and that being the case, it has been found more convenient and satisfactory to apply ligatures to each orifice requiring artificial closure. Hæmorrhage from veins usually ceases spontaneously when the position of the part is attended to, and all pressure removed that might prove an obstacle to the venous return. If it should be found obstinate, pressure applied to the orifice will be sufficient. Under any circumstances, cauteries and caustics are now seldom if ever required for arresting hæmorrhage.

Wounds. These remarks naturally lead to the consideration of incised wounds, and here we again find that simplicity and improvement in surgery are synonymous. "Hot dressings, filthy unguents, greasy poultices, stimulating plasters, and complicated bandages, have given place to light water-dressing, unirritating plaster sparingly applied, and careful position of the part."¹ To no one does a larger share of merit belong in this, than to him from whom we have made the above quotation; and we cannot do better than continue to glean from him a little more on this subject. "Formerly (and they are even still) wounds were put together without delay, and their edges squeezed into apposition, and retained

Surgery. by various means, such as sutures, plasters, compresses, and bandages. They were carefully covered up, and concealed from view for a certain number of days. Then the envelopes of cotton and flannel, the compress-cloths, the pledgets of healing ointment, and plasters, were taken away, loaded with putrid exhalations, and a profusion of bloody, ill-digested, fetid matter. A basin was forthwith held under the injured part, and the exposed and tender surface was deluged with water from a sponge, and then well squeezed and wiped. Then came a re-application of retentive bandage, of the plaster, of the grease mixed with drying powder, all surmounted by some absorbing stuff, as charpie or tow, to soak up the discharge. This was not unaccompanied by pain, often more complained of than that attendant on the original injury or operation. This process was repeated day after day, the patient was kept in a state of constant excitement, and often, worn out by suffering, discharge, and hectic fever, fell a victim to the practice. The wound was, as it were, put into a forcing bed, excited action beyond what was required was hurried on, and the consequence was, that immediate union seldom if ever could or did take place. A suppurating surface, on the contrary, with bad profuse discharge, and a very tedious cure, if any, were obtained." This was an uncomfortable state of matters, but there is now a change. Surfaces are not disposed to unite for many hours after the division and separation have occurred. So long as there is oozing of blood, no good end is to be attained by their close apposition. Should this be attempted, the blood which continues to be discharged from the smaller vessels is necessarily prevented from escaping; and the consequences are, infiltration of the loose cellular tissue, distention of the cavity of the wound, and separation of the surfaces probably throughout their whole extent. Then ensues a congested state of the surrounding vessels, with perhaps a troublesome hæmorrhage from branches that would otherwise have become sealed up; at all events, much constitutional disturbance, a heated swollen state of the injured parts, profuse, bloody, and putrid discharges, must occur; and this will certainly be followed by wasting suppuration from a foul cavity, which will be long in assuming a healthy action. It is only when re-action has occurred, when gentle vascular excitement has taken place in and around the solution of continuity, and when plastic matter begins to be secreted and thrown out, that the process of adhesion can be expected to commence. The edges of a large wound, as that resulting from amputation of the extremities, may be approximated in part, either by position, or by a few points of interrupted suture, as soon as bleeding from the principal vessels has been arrested. But the close apposition, and application of all the retentive means, had better be delayed for six or eight hours at least. In the interval, sensibility will be abated, the oozing moderated, and the chance of secondary hæmorrhage much diminished, by lightly covering the parts with lint dipped in cold water, and frequently renewed; or a piece of lint may be placed between the cut surfaces, and a constant irrigation of them be kept up for some time, by threads passing from a vessel containing cold water. When all oozing has ceased, and the surface become glazed, the surrounding skin, previously shaved, is made thoroughly dry; coagula are removed, the edges are put carefully and neatly in contact, and are retained by narrow slips of adhesive plaster placed at intervals. The plaster commonly in use does not retain its hold sufficiently long, is loosened by discharge, heats the surface, and often gives rise to erythema. A better kind is made by spreading a strong solution of isinglass in spirit on the unglazed side of oiled silk, cut into slips of the necessary length and size;

¹ Liston's Practical Surgery.

Surgery. this plaster is quite unirritating, and often retains its hold until the very completion of the cure. Being transparent, it does not prevent any untoward process that may be going on underneath from being observed; and if any fluid collects under it, an opening can be made for its escape. If sutures have been previously employed for the partial approximation of the wound, they can be removed by cutting the thread, shortly after the fixing of the plasters, for these alone are sufficiently retentive. No other dressing need be employed in the first instance; no compress, no pledget, no bandage; for in general they will not promote union of the wound, and may do harm. The slight discharge that oozes out is from time to time wiped from the surrounding skin, and from the glazed cloth on which the part is laid. In some cases of amputation, after a few days a roller may be applied, to encourage the subsidence of any slight œdema that may have arisen, and to bring the stump into a good form. By such simple treatment, a great deal of suffering is saved to the patient, and he enjoys much comfort and cleanliness; besides, the surgeon is relieved from a load of most unpleasant and harassing duty.

Wounds produced accidentally are almost always attended with more or less bruising of the parts, and can be united only by the second intention. After bleeding has been suppressed by the method recommended for incised wounds, the cold applications are to be superseded by those of an agreeable warmth, such as poultice of bread and water, or, what is much to be preferred, from its simplicity and lightness, lint of thick texture, and of sufficient size to cover the wound, soaked in tepid water, and overlaid by an ample piece of oiled silk to prevent evaporation. Heat and moisture, by which qualities a poultice produces its soothing and beneficial effects, by which the surface is relaxed, its capillary circulation encouraged, and discharge promoted, are thus amply afforded, without any of the weight, putrefactive fermentation, stench, and filth, inseparable from the best of common poultices. The edges of the wound are approximated as much as possible by attention to position; and by the same means the return of blood is favoured, and engorgement of the vessels and inflammatory swelling prevented to a very great degree. If the wound run across the fibres of the skin and muscles underneath, these are to be relaxed by flexion or extension, as may be, of the neighbouring articulations. Rest of the injured parts is also essential, and to obtain this it is sometimes proper to apply splints. Contraction of the wound takes place naturally, and generally with sufficient rapidity; should the surface, however, from any cause become weak and flabby, the lint is to be wet with a gently stimulating solution, as of zinc, instead of tepid water. Support, by bandage or plaster, may for a like reason sometimes be required. But healing is often retarded by the plasters and bandages which are inconsiderately employed to hurry it on; the granulations are absorbed, the surface of the sore becomes foul, the discharge thin and offensive, perhaps inflammation of the surrounding skin takes place, with extension of the sore by ulcerative absorption. Sometimes adhesion and suppuration may be happily blended in the cure. Thus, when, in a suppurating wound, whether accidental or incised, the discharge begins to thicken, and diminish in quantity, when the granulations are florid, small, and acuminate, and when the surrounding parts are sufficiently lax to admit of easy approximation, the granulating surfaces may then be brought into close apposition, with every prospect of immediate adhesion taking place.

Under some circumstances, the rule laid down as to the

propriety of delay in permanently closing wounds, may be departed from with advantage; as when the entire surface can be brought into close and accurate apposition, so that no clot of blood can be interposed; as, for instance, in penetrating wounds of the mouth; in division of the lip, as for harelip; and in repairing some deficiencies of the genital organs. In such cases, either the twisted or quilled suture is used, usually the former, and no other dressing should be applied. To put on strips of plaster, to cover the part with lint smeared with ointment, to interpose dossils of lint between the skin and ends of the pins, to support the wound by a uniting bandage—all this is mischievous, and a remnant of the old meddlesome surgery. Any kind of application collects and retains the secretions, heats and excoriates the surface, promotes suppuration, and interferes with the process of union.

Such is an outline of the simple treatment of wounds now employed, with the happy effects of saving the patient from much pain, and the surgeon from much trouble; obtaining a more frequent occurrence of adhesion in incised wounds; shortening the process of suppuration, and depriving it of much of its inconvenience. It is almost needless to observe, that this, as well as every other treatment, will however prove of little avail, unless accompanied with a careful attention to the general health: in other words, the surgeon, not hesitating to encroach thus far upon the duties of the physician, must ever be employing his medical science.

In no class of diseases is the operating knife now more happily in abeyance, in comparison with former practice, than in affections of the joints. Many a limb is now saved, with its usefulness little if at all impaired, that would, in days not long passed, have been doomed at once, and with very little ceremony, to amputation.¹ This important saving of life and limb is mainly attributable to the advance of pathology. The cultivators of that science, among whom the name of Brodie deserves prominent notice, have shown with great perspicuity the various changes which morbid actions induce in the structure of articulations, and established a wonderfully accurate diagnosis of each affection. We can often tell in what tissue of the joint disease originated, of what nature the morbid action is, and can predicate almost with certainty the actual state of the parts, as to extent and manner of degeneration. According to the principle that "the knowledge of a disease is half its cure," great advantage is thus obtained in adopting and regulating the treatment suitable to the circumstances of each case. Besides, we can tell at once, and with tolerable accuracy, in what cases we shall probably succeed; and in those in which we are made aware that the disease is of such a nature, or has proceeded to such an extent, as to baffle all attempts to cure, we are enabled to save valuable time, and thereby to save life, by proceeding at once to the only cure available, amputation. In whatever part of the joint diseased action may have originated,—bone, cartilage, bursa, or synovial apparatus,—if not arrested, it soon extends to all, converting the whole joint into one mass of disorganization. It is of the utmost consequence, therefore, to be early in the employment of the appropriate means of cure. The first and most important object is to secure absolute want of motion in the diseased parts; and here it is that the greatest improvement has taken place in the treatment of joints. "If perfect repose and quiet of the affected parts be omitted, all other means are found nugatory, and were as well untried. Nothing but disrepute can accrue to the profession, if hot irons, moxas, and issues continue to be used inconsiderately, to the neglect

¹ John Hunter himself seems to have been in the habit of making very unwarrantable abbreviations of living limbs, as the following anecdote abundantly proves. "He once had a patient whose leg he considered it necessary to remove. He had got on his *dress*, and a profound silence reigned in the theatre. The surgery-man disappeared. In two minutes he returned alone, with a face as long as the leg. 'Why do you not bring in the patient?' demanded the expectant operator. 'Because, sir,' said the astonished surgery-man, 'because, sir, he has run away!'" It is to be hoped that the custom of amputating legs that are able to "run away" has fallen into complete desuetude.

Surgery. of more powerful and less appalling means. Instant relief invariably follows the securing a state of perfect rest; other means, local and constitutional, are thus afforded a fair chance of doing good, and the natural efforts towards a cure are no longer thwarted and interrupted. But, above all, the effect on the general health is most remarkable and cheering. Even in very complicated and bad cases, in which sinuses communicate with the cavity of the joint, and the heads of the bones are ascertained to be in a state of ulceration, or partially necrosed, the good effects of perfect quietude of the joint will soon be manifested by cessation of pain, diminution of discharge, and speedy improvement of the general health. A cure of the local mischief may not be possible by this means alone, but much will often be gained, as regards the success of ulterior proceedings, by the rapid and certain amendment of the patient's condition." This salutary rest is the first part of the treatment of all diseased joints, and is continued, in general, throughout the whole period of cure; it is obtained by the application of splints, varied in form and construction according to the particular joint affected.

Disease of the soft parts of the joint usually commences in an inflammatory form, requiring depletion; when acute, the antiphlogistic treatment, local and general, must be very active, so as at once to arrest the morbid action; and hot fomentation and poultice will generally be found more soothing than cold applications. When the more violent symptoms have subsided, the disease giving way, a determination to the surface, with discharge, lends powerful aid towards its final extinction. For this purpose vesication may be produced, by cantharides or by nitrate of silver; or an eruption may be established by friction with a liniment of croton oil, or an ointment of tartrate of antimony, their strength proportioned to the nature of the part, and age of the patient. In chronic swelling of a joint, whether the effect of inflammatory action, or slowly and gradually supervening after injury, the diseased action must not only be arrested, but absorption also procured of the deposit and effusion within the synovial capsule and bursæ. To obtain the former indication, local depletion and counter-irritation are employed, according as the circumstances of the case require; and to obtain the latter, uniform pressure of the whole swelling, and gentle irritation of the surface, are combined with the means of securing the all-important rest of the joint, according to the method first recommended by Mr Scott. The limb having been uniformly supported by a roller, from its extremity up to the diseased articulation, the surface of the swelling is covered by lint spread with some gently stimulating ointment,—soap cerate with camphor, for example, or that with a greater or less proportion of the unguentum hydrargyri; and the whole articulation is then surrounded by long strips of adhesive plaster, drawn with moderate and uniform tightness, so as to support and gently compress the parts, without producing absolute pain or uneasiness. Above all, splints are applied to secure total immobility from motion; and they may either be of leather or wood, as most suitable to the joint affected. When this dressing has become loose, from subsidence of the swelling, it is re-applied as often as may be necessary. Should fresh excitement occur in the joint, from any accidental cause, during this treatment, the apparatus must be discontinued, until such excitement has been subdued by the usual means already described; and when the pressure is resumed, it should at first be very moderate. During the treatment the limb must be kept or gradually brought into the most advantageous position for ultimate use, particularly if, from the duration, nature, and extent of the disease, there is reason to expect impairment of the joint's motion. Thus, by steady extension with splints, the knee-joint may be brought into nearly a straight position, so that it shall be serviceable in progression; and the elbow may be bent, to form a right angle

with the humerus, so as to be convenient for prehension. But such alterations of stiffened limbs must be proceeded with very cautiously, otherwise they may occasion undue excitement, and consequent renewal of disease in the joint.

The preceding treatment will be found applicable to almost all joints, the hip not excepted. In morbus coxarius, for example, it is useful for securing immobility of the articulation, an object of such paramount importance towards arresting the progress of that formidable disease; and in its advanced stages it is productive of at least relief. The joint is placed extended, that being the preferable position, in case of ankylosis, and surrounded by "soft lint soaked in a strong solution of gum acacia, which is laid on in strips over the side and pelvis, from the short ribs to the knee, and made to embrace the limb fully. A layer of dry lint is first applied, and then two or three others, soaked in the mucilage, follow: these are covered by a fold or two of coarse calico, and the whole is retained by a roller." Sometimes it is necessary to preserve the limb steadily in position by a wooden splint, as in fracture, until the composition has dried, and the splint, so formed, adapted itself closely to the parts. "This gum-splint can be made of any form, so as to allow of its being taken off, trimmed, lined with wash leather, or protected with a layer of oiled silk, and re-applied with a clean bandage. It can also be fashioned so as to leave any part exposed: the discharge from issues and abscesses can thus be allowed to escape, and the parts can be dressed, and otherwise attended to, without disturbing the limb. In fact, the apparatus can be varied as circumstances demand, and is applicable in a great variety of cases, and to any articulation." A similarly useful splint is made "of leather dressed without oil, cut to a proper form, moistened in hot water, and applied with a roller. It soon becomes firm, and forms a case which fits the part accurately; it is then pared, fashioned neatly, and lined. In many chronic cases such splints answer admirably; but the gum-splints can be applied with less disturbance of the limb, which in many instances is a great recommendation."

"In the painful and dangerous affections of the articulations, when the cartilages are extensively absorbed, and when the cancellated texture of the bone is more or less diseased, good effects may yet follow judicious treatment. Besides following out the principle of preventing all motion, great relief will often be experienced from establishing a permanent discharge from the neighbourhood of the diseased tissues. This can be done simply and effectually, without causing alarm, or exciting much pain, by confining a small piece of caustic potash on the skin near the diseased joint. The sore thus formed is deepened, and made to discharge freely, when disposed to heal, by a few hours' application of the antimonial ointment. A seton may be preferred in some situations: certainly discharge can be thus kept up, and derivation obtained from the affected parts, fully as well as by actual cauteries, moxas, pea-issues, or other farrier-like practices. Great care must be taken in the placing of issues; they should be near to, but not upon a joint. Serious results have sometimes followed their careless application; diseased action has been increased, they having reached, or even penetrated, the synovial capsule."

By the careful and judicious employment of such treatment, many affections of joints which resisted the less simple modes of cure formerly in use, are now successfully combated; and many limbs are saved which our forefathers would not even have attempted to cure. But still there are too many cases which baffle all efforts to arrest the progress of morbid action; and it becomes necessary, in order to relieve the labouring constitution, and preserve life, to remove either the diseased parts alone, or the remainder of the limb along with them by amputation. The former **Resection** operation is termed resection, and is the preferable, because of joints. the less mutilating and severe, when the case is such as to

Surgery. promise a tolerable certainty of success. Should it fail, amputation then becomes necessary; but by the failure, the chance of the patient's ultimate recovery is very much diminished. The cases for resection, therefore, should be carefully selected. The general health must not have been much impaired; the soft parts must not be extensively affected; the disease must be almost entirely limited to the articulating surfaces; the joint must be such that the bones can be reached easily, and without the risk of wounding parts of great importance; and the patient must be of that age and constitution most favourable to the reparation of injury. The articulating extremities of the bones are exposed by free incisions, planned according to the circumstances of the case, and the diseased portions are removed by suitable saws, or by cutting pliers. The soft parts are then replaced, and the cavity treated as a suppurating wound, the intention being that it should heal by healthy granulations from the bottom. In patients tolerably advanced in life, it is well to keep the maimed joint in perfect quiet, and in the position most favourable to the subsequent use of the member, in order that the cure may be by ligamentous ankylosis, otherwise the limb will prove weak and not much available, and disease will be liable to return. But in young persons of healthy constitution, motion of the part is encouraged during the cure, with every prospect of the new articulation becoming both free and strong. The elbow-joint is the one to which the operation is most applicable. In the shoulder-joint it sometimes is expedient, also in the carpus and tarsus; but in the knee and hip joints experience loudly forbids its performance.¹

Amputation.

When however all milder means have failed, and resection is inapplicable, amputation must not be deferred until the disease has grown riotous in its progress, and the general health has been seriously impaired. When the surgeon is satisfied that amputation has become absolutely necessary,—that nothing else can save life,—the sooner it is performed, the greater is the chance that this severe remedy will not fail in its issue; and it is consolatory to reflect that modern improvement has greatly mitigated its horrors, and increased the probability of its success. It is performed more rapidly, more skilfully, and the suffering is infinitely less both during and after the operation. The tedious dissection of a limb, called the “circular method,” has now given place to the “flap-operation” by transfixion; the only valid objection that can be brought against which is, that perhaps a greater surface of wound is made; but this is much more than counterbalanced by the many benefits which it otherwise insures. The operation is more rapid, and less painful; the cut surface is smooth and regular; adhesion, or union by the first intention, is much more frequent; whether union be by the first or second intention, the cure is more speedily completed; the end of the bone is infinitely better covered, and the stump consequently more useful; and if the flaps have been skilfully formed, there will be no exfoliation of the end of the bone protruding through ulcerated integuments, and no formation of excruciating neuromata in the cut extremities of the nerves, rendering a renewal of operation necessary for final cure. The manipulations of the flap-operation are simple and well known, so need not be here detailed; but some rules necessary for its dexterous accomplishment are not always sufficiently attended to. The first regards transfixion; and it is, that after the first flap has been formed, the knife should not be again entered close to the top of the wound, but about an inch below, as thus cross-cutting of the integument is avoided. Another is, that in sawing the bone, the surgeon must not trust the distal portion of the limb entirely to an assistant, but, grasping it in his left

hand, must himself regulate its support, and so avoid splintering the bone. Pressure to command the bleeding need not be severe, but must be true. As was formerly stated, the tourniquet is seldom if ever used when the fingers of an assistant can be obtained who is cool, steady, and well conversant with the course of the vessels. The pressure thus obtained is not applied until the instant the incisions are commenced, and then only on one point; the limb consequently is not gorged with blood, as it would have been by the ordinary tourniquet: less blood therefore is lost, and besides, the flaps are much more easily retracted from the bone. When skilful assistants cannot be obtained, or when it is probable that many vessels will require ligature, and that consequently pressure must be long continued, a strong metallic spring may be used, each extremity terminating in a pad, one placed over the course of the vessel, the other resting on the opposite part of the limb: the assistant preserves its just application, and regulates its pressure, and the risk is avoided of his fingers giving way from cramp or fatigue. When the surgeon, from want of other means, is compelled to use the ordinary screw-tourniquet, its principal pressure should never be applied until the moment before incision; and as soon as the larger vessels have been secured, the whole apparatus should be removed, as thus the loss of much blood by regurgitation, and particularly from veins, will be avoided. The arterial orifices are secured by ligature, according to the method already mentioned; and should the venous trunks continue to pour out their contents, notwithstanding the removal of all constriction of the limb, pressure by the fingers of an assistant, though for only a short time, usually suffices to arrest the hæmorrhage. The wound is treated according to the principle of delay formerly explained; and thus adhesion is not only favoured, to the saving of time and pain, but the occurrence of secondary bleeding is also made much more improbable; for no warm coagulum is bound up in the wound, to act as a sponge, and encourage escape of blood from all the untied vessels; and even when it does take place, the bleeding point is much more easily secured than when the stump is bound up tight and close from the first. Should the stump bleed seriously, six, eight, ten, twelve, or fifteen days after the operation, in consequence of sloughing or some other unhealthy action having supervened, the ununited wound is to be laid open, all coagula removed, and direct pressure applied. But should this fail, the surgeon ought instantly to secure the trunk of the vessel whose branches are at fault, at some distance above the stump—in amputation below the knee, tying the femoral, for example—at the same time supporting the stump by bandage. This practice has been found almost invariably successful.

Amputation is also less frequently resorted to in cases of severe injury than formerly. In fractures, skilful and careful management preserves many a limb useful and but little out of shape, which before would have been considered too seriously injured to retain its vitality. Nor are compound luxations regarded with the same dread. In compound Dislocation of the ankle-joint, for example, with protrusion of the bones, instead of at once amputating the limb, the dislocation is reduced, the protruding portions of bone having been removed in whole or in part, if so injured as to render that proceeding necessary; the limb is retained in a favourable position, and in a state of complete rest; the wound is treated by the simple soothing plan; undue excitement is warded off or held in subjection by the usual means; if abscesses form, they are early evacuated; the parts are uniformly and gently supported; the surgeon's medical acquirements are kept constantly on the alert; and thus, in very many cases, the limb is retained, with the injured joint,

¹ For further information on resection of joints, see Mr Syme's excellent treatise on this subject.

Surgery. though stiff, exceedingly useful. The ordinary simple dislocations are now at once detected by the observant and well-educated surgeon, and as readily reduced if recent; so that branch of the profession promises to be soon rescued completely from the maltreatment of ignorant empirics.

Fractures. The whole treatment of fractures has been simplified and improved; the process of reparation in disunited bone is better understood, and the means which favour it are more skilfully and effectually adapted. In fractures, whether compound or simple, of the smaller bones, more particularly of the upper extremity, the gum-splint will be found very suitable. By the employment of these or other light splints, —of wood, pasteboard, leather,—well padded, so as not to fret the integument, and always of sufficient length to command the neighbouring joints, the bones are not only kept accurately in their proper place, but perfect quietude and freedom from all motion are likewise secured,—a point all-important here, as in the treatment of diseased joints. Broken limbs are no longer laid out in state on pillows, altogether unrestrained. Absolute rest, following early reduction of the bones, and combined with strict attention to the workings of the general system, usually succeeds in preventing interruption of the cure by undue excitement in the neighbourhood of the injury. Should this nevertheless occur, the retentive apparatus can be so arranged as to admit of the part in fault being attended to as freely and as often as is necessary, without disturbance of the rest of the limb; for example, blood may be abstracted locally, fomentation or poultice applied to a particular part, abscesses opened, and wounds dressed, without undoing all the retentive apparatus, and so jarring the fracture. In severe compound fractures this advantage is particularly important. The soft parts can be looked after as well as if no apparatus at all were applied; and the untoward results likely to follow such a serious accident can consequently be sometimes averted, and always moderated, while the hard parts are uniformly kept in the condition most favourable to their union. In fractures of the lower extremity near the hip-joint, Desault's splint is still in use, somewhat modified. When the break is lower in the limb, an improvement of Macintyre's double inclined plane is by much the most suitable apparatus, combining in an eminent degree the advantages of complete rest of the whole limb, with ready and convenient dressing of particular parts.¹ The patient is also able, with safety, to be out of bed, and in the erect posture, at an early period of the cure; a circumstance very favourable to the preservation of the general health.

Gangrene. When, notwithstanding care and skill, gangrene occurs after severe fracture, either immediately, or in consequence of greater vascular excitement having taken place than the hurt parts are able to bear, amputation must be had recourse to, and the period of its performance is now no longer a subject of dispute. It must be done immediately, in sound parts, at a distance from the gangrene, without waiting for a line of separation, as in chronic gangrene, else the surgeon will expect the opportunity in vain, and meanwhile his patient will sink.

Disunited fracture. Sometimes, either by the carelessness of the surgeon and inefficiency of his treatment, or from the fault of his patient or defect of his constitution, union of the fracture fails to take place. In recent cases of such disunion, adjustment of the broken ends in accurate apposition, and undisturbed rest of the fracture and of the whole limb, will occasionally effect a tardy union. But usually it becomes necessary to rouse the parts; and the method now followed, the most convenient, as well as most successful, is the introduction of a seton between the fractured extremities, gradually increasing the size of the tape, but taking care to remove it altogether as

soon as it appears that excitement has been produced, sufficient for establishing the regenerative process. A few days are usually enough; when ignorantly permitted to remain for a long period, the mere presence of the foreign body, and more particularly the constant discharge which it maintains, tend most powerfully to prevent the result in favour of which it was employed. After removal of the seton, the limb is placed in the proper position, and must be preserved in a state of most complete rest.

In fractures and other injuries of the cranium, the trephine is now used with better judgment than formerly; it is more sparingly in most cases, more readily in others. It is not considered necessary to convert every fissure of the skull into a chasm, by following it out with the trephine; in depressed fracture with compression of the brain, the application of the trephine is imperative, but no more bone is taken away than is necessary for the raising of the depressed portion, and the removal of what is so injured by the accident as to render its retention of vitality improbable; and to bore one or more holes in the cranium in search of extravasated blood, is generally regarded as a proceeding equally mischievous and unprofitable. But in punctured fracture, the necessity for the trephine is urgent; it must be used freely and at once; and as this important point of practice is perhaps not yet sufficiently attended to, we shall be a little more explicit on the subject. The punctured or star-like fracture is occasioned by a sharp body striking the head with considerable force. The integuments are divided, and the surface of the bone presents an appearance of injury somewhat resembling what is often seen in ice when struck in a similar way. But this is a very slight extent of damage compared with what the inner table suffers, when the puncturing weapon has passed through the *diplôe*, as is usually the case. The inner table, being by much the more vitreous, is shivered into numerous *spiculæ*, which being driven inwards by the force of the blow, perforate, or at all events grievously irritate, the coverings of the brain, producing inflammatory action, soon affecting that important viscus, and, if not arrested, proving speedily fatal. After the infliction of such an accident, therefore, even should the patient be at the time so little affected as to walk to the surgeon to have his wound dressed, the trephine should be immediately applied to the punctured point, in order that a portion of the bone may be removed, sufficient to allow extraction of all the displaced portions of the internal plate. In no other way can we avert intense inflammatory action from the wounded *dura mater*, extending in all probability to the brain and its more immediate investments. Even should the practitioner be in some degree successful in moderating the more immediate mischief by antiphlogistics alone, the necessity for trephining will still remain, on account of abscess under the bone, occasioned and kept up by the *spiculæ*; the matter must be evacuated, and the cause of its formation must be removed. It is surely infinitely better, therefore, to operate in the first instance, and so avert all such calamities. Abscess sometimes forms between the *dura mater* and the bone, as a consequence of mere contusion; its occurrence, and usually its site, are indicated by constitutional disturbance, peculiar œdema of the scalp, unhealthy discharge from the wound, and a pale necrosed appearance of the bone. In such cases, also, perforation of the skull should not be delayed; for it will usually succeed in evacuating the matter, and relieving the patient. But, on the whole, "trepanning of the skull, which, with our forefathers, appears to have been an everyday occupation, is an operation now very rarely resorted to." After its performance, from whatever cause, there is now no rasping of the bone, or cutting away of the integuments; the edges of the circular aperture are denuded of their pe-

¹ For more minute details regarding these splints, see Liston's Practical Surgery, p. 80, *et seq.*

Surgery. riosteum as little as possible, and the soft parts, having been carefully replaced, are treated as a suppurating wound; the deficiency of the bone is filled up by a ligamentous expansion, incorporated with the granulating integument. When a large portion of the skull has been removed, it is well to afford support to the cranial contents, by the application of a compress and bandage.

Erysipelas. There is no more successful caterer to the amputating knife than erysipelas inertly treated; destruction of bones and joints has been too often its result. The improved treatment by incision, however, now in general use, saves many a limb entire and unscathed. So soon as tension of the surface indicates that the cellular substance is so infiltrated as to threaten destruction of the tissues, free incision must be immediately had recourse to; the knife is used not only to evacuate matter, but to anticipate its formation, and prevent its baneful consequences. In the milder cases,—and in erysipelas of the face, where incisions cannot be practised with propriety,—sufficient relief is obtained by making, with the point of a lancet, numerous punctures in rapid succession; effusion from which is encouraged by hot fomentations. In most cases, even when severe, division of the integument and subjacent cellular tissue suffices; but if the infiltration has extended to the inter-muscular tissue, the knife must follow: its free use may appear harsh, but is in reality a valuable kindness. The burrowing of matter is prevented, and consequently also sloughing of the soft parts, the opening up of bursæ and articulations, and the denuding of bones by destruction of their periosteum, ending in necrosis more or less complete. Museums were at one time copiously enriched with splendid specimens of necrosis of the long bones, throughout almost the whole extent of the limb, all the result of neglected erysipelas; but the bistoury has superseded the amputating knife, and such preparations fortunately are now become valuable by their rarity.

Abscess. Similar remarks will apply to the early opening of abscesses in general. "Pointing" is not now waited for; before that takes place, irretrievable mischief may have been done. The *tactus eruditus* having acquainted the surgeon with the existence of purulent formation, it must be reached by his bistoury, at whatever depth, if it be in the neighbourhood of joints, bones, or vessels, and more particularly if close to important cavities or canals. The mere contact of purulent matter will not injure these, but its pressure will, and from it they must be relieved, lest their functions be interfered with or their structure destroyed. For example, purulent collections in the fauces are evacuated by the bistoury before the patient is threatened with suffocation; and abscesses in the perineum, and neighbourhood of the anus, are drained by an external opening before they have become troublesome fistulæ.¹ The knife must of course be used cautiously when the abscess is deep, lest the vessels and other important parts be wounded; but let not the fear of this deter the surgeon from relieving abscesses in their immediate neighbourhood, for "the vessels and nerves are displaced by the morbid accumulation, and the knife is passed safely, in their course, to such a depth as would greatly endanger them in the healthy state of the parts." The opening should in all cases be made sufficiently large to afford a free exit to the matter; it should be placed in the most dependent part of the cavity, with which view the prevailing position of the patient should be considered; and sometimes more than one opening should be made at once, to

prevent the necessity for future counter-openings, or the formation of sinus,—as when the abscess extends over a considerable surface, and cannot be made to discharge through one aperture. After evacuation, in assisting which no pressure or squeezing should be employed, fomentations and the water-dressing are applied. When the rule of early opening has not been attended to, and the abscess in consequence has become chronic and of large size, free incision should still be made at the most dependent point of the tumour, notwithstanding the advice of the late Mr Abernethy to the contrary; for experience has shown that the Abernethian treatment of chronic abscess is more likely to produce constitutional disturbance, with unhealthy excitement of the cavity, than when the matter is allowed a free and constant drain, and the parts are at the same time duly supported. In establishing an artificial abscess, or issue, the modern caoutchouc seton is a great improvement on the skein of silk or cotton formerly used, requiring no renewal on account of decay, and absorbing no discharge.

Ulcers. Ulcers, like wounds, are now treated more simply and better; and better because more simply. The healthy suppurating sore is covered, like a suppurating wound, with the plain and light water-dressing; simple in the first instance, afterwards medicated by gentle stimulants or not, according as the progress of the sore may seem to require. When stimulants are used, their solution is at first weak, and is increased in strength very gradually, lest the discharge should be suddenly suppressed and the sore consequently inflame; the object is simply to moderate discharge, and check weak exuberance of granulation. An inflamed ulcer is subdued by the hot-water dressing, combined with antiphlogistic regimen, rest, and elevation of the part. An irritable ulcer is soothed by the water-dressing, and occasional slight application of the nitrate of silver to the jagged angry edges of the sore; or the lint may be dipped in a bland anodyne solution. In all such dressings, the lint is kept constantly invested by a portion of oiled silk, larger than itself, to prevent evaporation of the fluid in which the lint has been soaked. When granulations prove exuberant, they are to be reduced to the proper level by the application of sulphate of copper, or may be shaved off by the rapid sweep of a thin sharp bistoury; or the surface may be compressed by dry lint and bandage. An indolent ulcer is stimulated to healthy action by pressure and support, combined if necessary with a direct stimulant application. This last description of sore is the most common, and is usually found afflicting the labouring classes, to whom the restoration of a limb is of more importance than to any other class of patients; a speedy cure is therefore of no little consequence. It is best effected by the method first recommended by Mr Baynton. When the patient applies for relief, there is usually considerable excitement around the sore, and this must in the first instance be corrected by the usual means. Then the foot and lower part of the leg, for it is the part commonly affected, having been uniformly supported by bandage, the sore is compressed by adhesive plaster, applied in strips encircling the whole girth of the limb, and with their extremities crossed over the sore; if this is large, and pouring out much discharge, it is well to cut a small hole in the plaster where it covers the ulcer. The application having been made to extend about an inch on each side of the sore, a little fine tow is placed above it, to absorb discharge, and the whole is retained

¹ Dr Radcliffe has probably few imitators at present in his clumsy method of emptying abscess of the fauces. "He was once sent for into the country to visit a gentleman ill of the quinsy. Finding (supposing) that no external or internal application would be of service, he desired the lady of the house to order a hasty pudding to be made; when it was done, his own servants were to bring it up. While it was preparing, he gave them instructions how they were to act. When the pudding was set upon the table, the doctor said, 'Come, Jack and Dick, eat as quickly as possible; you have had no breakfast this morning.' Both began with their spoons; but, on Jack's dipping once for Dick's twice, a quarrel arose. Spoonsful of hot pudding were discharged on both sides; handsful were pelted at each other. The patient was seized with a hearty fit of laughter, the quinsy burst, and the patient recovered." A moment's use of a straight sharp-pointed bistoury would have saved both time and the pudding.

Surgery. by continuation of the bandage which supports the lower part of the limb. This dressing is removed at the end of forty-eight hours, or sooner if necessary. The sore itself is not to be washed or rubbed, for its own secretion is its natural and best protection; but the surrounding skin is wiped clean, and, if excoriated by the pressure, bathed with a spirituous lotion; the dressing is then re-applied as before. By such manipulation, repeated as often as is necessary, the indolent surface of the sore is stimulated to the formation of healthy granulations for raising its depressed surface, while at the same time the swelling of the surrounding skin and cellular tissue is diminished by absorption; and thus, the sore and its margins having been brought to one level, cicatrization proceeds. After the ulcer has in this way been converted into the simple suppurating sore, either the same dressing may be continued, exerting less pressure, or it may be superseded by the medicated lint and oiled silk. When nearly closed, all dressing may be discontinued; the natural secretion forming a crust, under which cicatrization is speedily completed. Of course healing will be materially assisted by rest and elevation of the limb; but the labouring man cannot always afford this, and the treatment by plaster, just described, possesses, in addition to its other virtues, this advantage, that with it the patient can continue in the erect posture with much greater impunity than when using any other application. For some considerable time after cicatrization, the limb should continue to be supported by a bandage or laced stocking. Another frequent ulcer is the weak sore, with thin, dark-red margins, based on cellular tissue almost sloughing, and emitting a thin unhealthy discharge. Such generally form in clusters, and can be brought to heal only after the unsound parts have been destroyed by the potassa fusa, so as to obtain a sound foundation on which the reparative granulation may arise. This description of sore, however, is too often combined with and dependent on a strumous diathesis, and is healed only to break out afresh.

Such is a bare outline of the modern treatment of ulcers, to which however no fixed and absolute rules can be made to apply; for sores are often changing their character and appearance, though perhaps but slightly, and consequently demand as frequent a change in the treatment. "A judicious practitioner, by varying his applications according to the appearance and disposition of the sore, will serve and benefit his patient much more efficiently than by trying empirically this or the other new specific, or blindly applying one remedy for every sore, because he has seen its good effects, or been informed of its answering miraculously in one or two instances." Be it likewise remembered, that in no class of diseases is attention to the general health more requisite.

Hospitals. We may here allude to the general improvement in hospital practice, in consequence of which the hospital sore, so long and so frequently a scourge in those valuable institutions, is now almost unknown. The ventilation, cleaning, and general arrangement of the wards, the diet, clothing, and classification of the patients, are all improved; but probably nothing has tended so much to the disappearance of this formidable disease, as the substitution of tow for sponge in the dressing of sores; a change apparently simple and insignificant, but in reality most important. Formerly both nurses and dressers were in the habit of using one sponge for the sores and wounds of a whole ward, and if in one patient unhealthy action supervened, the vitiated discharge was soon afforded an opportunity of inoculating all. Now, sponges are not seen but in the operating theatre; washing of wounds and sores has been discontinued, because found to be preju-

dicial to cicatrization; and when the parts around require Surgery. cleansing, this is effected by means of tow, which, when used, is immediately thereafter destroyed or thrown away.

In aneurism, the discovery of Hunter has been most successfully extended. Further investigation in arterial pathology, especially as to the effects of ligature, has produced the most important results. The accumulated knowledge and experience, applied to practice by the talents and courage of Scarpa, Abernethy, Astley Cooper, Liston, Stevens, and Mott, have achieved most triumphant advancement in surgery; for thus the means of cure have been happily extended to cases of aneurism, formerly regarded as irremediable. There are many aneurisms, and not of unfrequent occurrence, on which the surgeons of the last century were content to look until the tumour burst, and their patient perished under their very gaze, which are now fearlessly encountered, and with the best hopes of success. In aneurism of the neck, Hunter and Scarpa led the surgeon to believe that a ligature placed on the carotid, between the tumour and the heart, might effect a cure, and Cooper proved that it did so. This arresting of the cephalic circulation is no longer looked upon with insurmountable dread; for experience has shown, that even both carotids may be tied, with but a short interval between the operations, and without any untoward result. The surgeon's knife and ligature have, in the cure of aneurism, ventured even so near the heart as the arteria innominata, but hitherto unfortunately without ultimate success; indeed it is doubtful whether the operation on this vessel can ever prove successful, there being so many inevitable obstacles to complete consolidation by ligature; as yet, ulceration has always supervened, occasioning fatal hæmorrhage. The subclavian has been deligated on account of axillary aneurism. Mr Liston had the honour to be the first who did so with success; and an equally happy result has not been unfrequent since. Ligature of the axillary and humeral arteries, though difficult, is regarded as scarcely unusual. The aneurisms of the groin and hip were left to run their course unmolested, until Abernethy and Stevens showed that the Hunterian operation could be extended even to them. "The common, external, and internal iliacs, are now tied without much difficulty, and very often with a successful issue. These operations are quite justifiable, provided always there has been no mistake in diagnosis, and that there is nothing in the state of the patient's health, or in the condition of the arterial system, to contra-indicate interference." The original operation on the femoral, on account of aneurism in the ham or in the lower third of the thigh, is now looked upon, when skilfully executed, as at once the simplest, most beautiful, and most successful interference with the larger arteries. Thus we see that all aneurisms of the extremities are within the reach of art, and that a certain degree of success has attended the approaches towards the trunk, as far as the common iliac and arteria anonyma.¹ It is to be feared that "the force of surgery can no further go." It is indeed a triumph that it has gone so far; and we cannot reasonably expect that ligatures, placed nearer the great centre of circulation than either of the above-mentioned vessels, can ever be productive of a successful result. Surgical invention and enterprise have not, however, been easily baffled; and in those cases of aneurism too deep to admit of the Hunterian method of operation, it has been proposed to reverse the procedure, and place a ligature on the distal side of the tumour. The operation has been put in practice, and in a few cases with some temporary advantage, but the general result is not encouraging. Great difficulty has sometimes been experienced in discovering the vessel destined for the ligature, in consequence

¹ The aorta has been tied, but with a result which does not warrant repetition of the experiment.

Surgery. of displacement by the tumour, or more or less obliteration of its calibre. It is an operation "which, in a favourable case, and at the earnest solicitation of a patient, a surgeon might be induced to adopt, as the only though desperate remedy for an otherwise incurable disease; but it is not a proceeding which he would be warranted in urging his patient to undergo." In false aneurism from wound, as at the bend of the arm, if pressure methodically and firmly applied—the whole limb below the wounded point being duly supported—fail to arrest the formation of tumour, recourse is had to the ligature. If the tumour be recent, soft, and superficial, and the parts around not much infiltrated, the wounded point may be exposed at once by incision, and ligature placed above and below the aperture. But if the tumour be of considerable duration and size, ligature of the trunk, between the tumour and heart, is the preferable and equally successful proceeding.

The more important steps in effecting deligation of the larger arteries, whether for true or false aneurism, may here be briefly mentioned. The incisions are made with a small, finely-edged scalpel, used lightly and cautiously; neither directors nor blunt knives should be employed, for they must bruise or tear to a certain extent; and the simpler and smoother the cut is, the greater is the probability that both wound and artery will assume a healthy action. The vessel having been exposed, its sheath is opened on the anterior aspect, to the extent of about an inch, and the point of a blunt aneurism-needle is gently passed beneath and around the artery, great care being taken to exclude nerve and vein from its circuit. A strong silk ligature having been thus passed, its loop is cut, and one half withdrawn along with the needle; the other is firmly secured on the artery, its effect on the tumour having, by previous pressure, been ascertained to be satisfactory. In placing the knot on deep-seated vessels, Mr Weiss's instrument will be found to afford important assistance. "All this must be done without disturbing the position of the vessel, without detaching it from the sheath, or breaking up its fine cellular connections laterally and behind, further than is barely sufficient for the passage of the needle. There must be no lifting of the vessel on the handle of the knife, or on the director, as if in triumph; for ulceration of the arterial coats, and secondary hæmorrhage on or about the separation of the ligature, are the almost inevitable consequences of such proceedings." If by accident the vessel has been disturbed from its connections, two ligatures are to be applied, one at each termination of the separated portion; but in general one single ligature is much preferable. Both its ends should never be cut away close to the knot; for, in addition to the ordinary disadvantages found to belong to this plan, there is no slight risk of abscess, caused by the deserted knot, inducing secondary bleeding by ulcerative absorption of the arterial coats. And indeed the surgeon will feel more comfortable, in such anxious cases, if he leave both ends pendent from the wound. For a like reason, separation of the ligature should be throughout its whole course spontaneous; rash pulling at its ends may be productive of the most serious results. The wound is brought together, and otherwise treated, according to the principles formerly detailed. Should secondary bleeding unfortunately occur, the vessel must be exposed above and below the source of hæmorrhage, and a ligature applied at each point. But if the original operation have been judiciously as well as dexterously performed, and the after-treatment carefully conducted, such an untoward result need scarcely be dreaded. Should pulsation return in the tumour, on the complete establishment of collateral circulation, pressure well applied will suffice to perfect the obliteration of the sac.

Veins.

In dilatation or varix of the veins, if methodical pressure and attention to the bowels fail to remove the disease, or

at least its inconveniences, a radical cure is obtained by obstruction of the calibre of the main trunk, on the cardiac side of the dilatation; and this is effected either by the application of potass, or by including about an inch of the vein, at that part, between two points of twisted suture; the needles being passed beneath the vessel, and removed as soon as sufficient excited action has been produced in the venous coats. Either method is effectual in obtaining obliteration of the vein's calibre at the selected point: the latter is, perhaps, in most instances the preferable; but in both the procedure must be cautious, and the after-treatment watchful, in order to guard against hæmorrhage and extension of inflammatory action.

The operation of phlebotomy has always been simple *Venesec-* and of easy execution; in regard to it, the only modern *tion.* improvement which we have to notice, is the comparative rarity of its performance. It was, and still is, too much the custom to bleed, so as to appear to be doing something active in treatment, not only when the proceeding has seemed to the ignorant practitioner likely to do no harm, but also when a wiser head could have told that it must do irremediable mischief. The good fortune of the first phlebotomist, Podalirius, seems to have produced in his successors an unfortunate attachment to the operation, which has been communicated from generation to generation, and from which our day is not yet wholly exempt. In very many cases it is doubtless the only certain means of relief, and must be employed readily and boldly; but in fully as many it had better be done with a sparing hand, or altogether omitted. What can be worse, for example, than to find a patient who has just sustained a severe accident—still labouring under the shock which the injury has produced, pulseless, and with the powers of the system all but extinguished—robbed by an ignorant or reckless man, unfortunately called to his aid, of that very fluid, and consequently of those very powers, of which he is at the time most in need, and without which the syncope must soon pass into death. Such a case is too frequent even now: but it is consolatory to know that the folly of such proceedings is becoming more and more extensively known, and that the thoughtless, mischievous practice of indiscriminate venesection is more and more abandoned.

A similarly absurd practice prevails in regard to the *Bruise.* treatment of bruise. Leeches are instantly applied, in order that they may suck out the extravasated, or "bruised blood," as it is called. These little animals drink only from the running stream, drawing for themselves from the blood-vessels, and therefore fail to perform what is expected of them by their employers. At the same time, their bites, admitting the external air to the extravasated blood, may induce suppuration of an unhealthy kind in the cellular tissue. They are of use simply as a mode of local depletion, in order to moderate or avert inordinate excited action occurring as a secondary result of the accident.

In the treatment of hernia, the advancement of anatomi- *Hernia.* cal knowledge has rendered operative procedure more simple, safe, and effective. And pathological experience having now fully established the great danger of delay after the taxis, fairly tried, has been found unavailing, the operation is had recourse to at once, with a much more certain prospect of success. In the greater number of cases the taxis will prove successful, when employed early and with skilful perseverance. But as soon as the surgeon is satisfied that his unarmed hands, assisted by his medical skill, are incapable of reducing the tumour, each moment of delay is culpable until he assumes the knife, and by it relieves the constricted parts; for by its keen edge the patient is infinitely less endangered than by even brief continuance of the incarceration. This principle, now generally acted on, saves many a patient who formerly would either have perished in excruciating torture, or lingered on

Surgery. with artificial anus, noisome to others, and a burden even to himself. But this is a subject too extensive to be here more fully considered. Endeavours towards the cure of artificial anus are made by the apparatus, and according to the system of treatment, invented by Dupuytren; and sometimes they prove successful.

Calculous disorders. In the treatment of calculous disorders, modern improvement has effected much. Chemistry, happily combined with pathology, has taught the surgeon in many cases to anticipate cure by prevention, detecting the tendency to deposit in the secretions of the kidney, ascertaining the exact nature of that deposit, and then applying, according to its nature, the suitable corrective. When there is reason to believe that calculus has actually formed in the bladder, its presence is to be ascertained by careful sounding. Many affections—for example, diseased kidneys or fundament, worms or other causes of irritation in the bowels—occasion all the ordinary symptoms of stone; and it is only after the surgeon has distinctly heard the stroke of his sound on the foreign body, that he can be certain that a stone exists. The most convenient instrument for exploring all parts of the bladder is a sound, steel throughout, with a sharp and sudden curve. When, by its cautious and patient use, the presence of a calculus is no longer doubtful, and some estimate has also been made of its size and form, the question then arises between patient and surgeon as to the preferable mode of its summary extrusion; for removal by chemical solvents, though sanctioned by act of parliament, is no longer trusted to. It is only within these twenty years that a power of selection has existed; till then, the knife alone presented hopes of relief. Now, however, *cutting* is often superseded by *crushing*, and rightly. Indeed it is a *questio vexata* among many, as to whether lithotomy or lithotritry be the better adapted for general use; and each has its zealous and uncompromising advocates. As is usual in such cases, we shall probably find that truth lies in the middle, and that both operations must still be employed, each finding cases to which it is peculiarly applicable. Lithotritry was at first a very imperfect art, difficult and complicated in performance, often failing in the attainment of its object, and not seldom followed by the most untoward results. Its practice was likewise in a great measure confined to a particular set of operators, not the best qualified for such undertakings, who, regarding it as a means of gain alone, were not long in bringing discredit on its reckless and indiscriminate use. Thus a great advantage was given to the old operation, over its imprudently managed rival. But the instruments and procedure of lithotritry have of late been greatly improved, and have become, as is usual in such improvements, more easy and simple, and at the same time more effective. They now receive the attention of every well-educated surgeon; the student applies to lithotomy and lithotritry with equal care and attention, and endeavours to perfect himself in the manipulations of both; and in consequence, the latter operation has been rescued from the empirical professor, and placed in the better qualified hands of the regular practitioner. There is not now, as in the time of “the invasion of professed stone-grinders,” some years ago, an indiscriminate performance of one operation, in all cases, simply because the operator knows no other. The circumstances of the case had then very little influence in determining the nature of the operative procedure. If a surgeon was applied to, the knife was recommended; and “if the patient fell into the hands of the professed stone-grinder, he was certain, under all circumstances, of being subjected to the hammering and boring processes.” Now, application being made to the regular practitioner, at least in the first instance, he, equally acquainted with either mode of operating, conscientiously advises the one which circumstances require, either operating himself, or employing one whom he may consider more dexterous and equally skilful. Lithotritry can only

Surgery. be safely performed by those “who understand well the healthy anatomy of the urethra and bladder; who are acquainted with their sympathies, vital actions, and pathological changes; and who understand and practise the treatment of their deranged functions.” And by such it is now performed, in the cases to which it is applicable. In patients above the age of puberty, when the symptoms have not been of very long duration, when the stone has been ascertained not to exceed a chestnut in size, when the urethra is free from contraction, when the bladder is capacious, tolerably healthy in its coats, and free from irritability of its lining membrane, and when the individual is of an easy, patient disposition; under a combination of such circumstances, lithotritry is the preferable operation; in other cases, lithotomy. It is thus apparent, that possibly lithotritry may in time almost entirely supersede lithotomy in the adult; all that is necessary being, that the patient apply to a well-qualified surgeon at the very commencement of his ailments. But until wisdom shall pervade mankind to this extent, very many cases must occur in which the old operation, well performed, is much to be preferred; and this need not be greatly regretted, for the actual difference between the two operations as to pain and danger is not so great as is generally supposed.

The simple instrument of two branches, as made by the Messrs Weiss, has superseded all the more complicated and less effective apparatus for lithotritry; as also Cooper's forceps for removal of small stones by the urethra. The instrument having been introduced into the bladder, tolerably distended, is brought in contact with the stone; its blades are opened, and the stone brought between, great care being taken that the mucous membrane is uninjured; the blades are then approximated by the screw, and the interposed stone crushed more or less completely. When the stone is single, small, and friable, one such proceeding will suffice: if not, the fragments are seized and bruised in succession, either at the time, or at one or more subsequent sittings. The screw-power is preferred to that of the hammer, as equally efficient and more safe, not endangering the twisting or breaking of the instrument. Diluents are freely exhibited, to promote and facilitate passage of the detritus with the urine. Should the pain and irritation thus occasioned prove severe, opiates, blood-letting, and hot bathing, may be required. But, in general, if the case have been judiciously selected, and the operation skilfully performed, the subsequent irritation will be but slight; and after a few days, examination of the bladder may be resumed, to ascertain whether or not all the fragments have been extruded. This exploration cannot be too minute and careful, for the greatest stumbling-block to the advancement of lithotritry in the confidence of the profession, has been the uncertainty as to whether or not the bladder has by such proceedings been completely freed from every fragment, it being well known that but a very small portion of foreign matter remaining will become the nucleus of further deposit, and speedily re-establish the disease. The advantage of lithotomy is, that, for final exploration of the bladder, it has the finger, which, if at all experienced, can seldom be deceived. Lithotritry has but the sound for the same purpose, and must endeavour to make patience, dexterity, and care, compensate for the inferiority of the instrument.

But when the stone is large, and has been long resident in the bladder, this viscus has its cavity contracted, its coats fasciculated, and its surface irregular, affording receptacles for the fragments, from which the most careful manipulations may not dislodge them. Besides, such a bladder will not bear the annoyance of instruments often introduced; indeed the mere change of a tolerably smooth stone into angular fragments, may be sufficient to excite even fatal disturbance of the viscus and of the system. In all such cases, therefore, lithotomy is the preferable operation; it

Surgery. not only insures, with common care, complete removal of the source of irritation, but also, by suspending the functions of the diseased viscus, gives it the advantage of rest, as well as the relief caused by loss of blood from the neighbouring vessels. Even when the bladder is tolerably sound, a large stone of ordinary consistence is unfavourable to lithotripsy; for the fragments must also be large, until after much manipulation; and attempts to pass such fragments must be attended with much pain and some danger. The immediate result of lithotripsy in such cases is, "like the partial delivery of a pregnant woman," very unsatisfactory. The fragments may become firmly impacted in the urethra, causing retention of urine, and all its direful consequences. When this happens, and the impacted portion will not yield to an attempt to push it again into the bladder, it must at once be reached and removed by incision in the mesial line; and then the surgeon may take the opportunity of extending the wound a little farther, and with his finger and a scoop effectually clear the bladder of all remaining detritus. Lithotripsy is scarcely applicable to young subjects; the parts are not sufficiently capacious, the patient is too restless, and the concretion, usually of oxalate of lime, is too hard to be easily pulverized. This is the less to be regretted, as in them well-performed lithotomy seldom if ever proves unfortunate. Among them, therefore, and "those of mature age who are so foolish or so ill informed as to permit the stone to attain an inordinate bulk," lithotomy must still prevail. It is an operation certainly more alarming to the patient, and to the surgeon may be more difficult and perplexing; but when dexterously and skilfully executed, we doubt much if its average risk exceeds, or even equals, that of promiscuous lithotripsy; its efficiency is indisputably greater. The mode of operation pursued by Mr Liston, the most dexterous, elegant, and successful lithotomist of the present day, is similar to the method of Cheselden. For its details we beg to refer to Mr Liston's late work on Practical Surgery, where the modern lithotriteur is also minutely described. He attributes much of his success to limited incision of the prostate, so as to preserve the internal cellular tissue of the pelvis from infiltration of urine; and to the insertion of a gum elastic tube in the wound, so as to afford a free exit to the urine, and diminish the risk of its poisonous infiltration, while at the same time it facilitates the arresting of hæmorrhage, should this occur. "The operation of lithotomy," says he, "if performed in the easy and simple method recommended, is effected with much less pain than is supposed; it is completed, with perfect safety, in a short space of time, and offers very favourable results. It is, however, an operation which ought never to be undertaken without due consideration of all the circumstances that may arise; and the surgeon who does undertake it must have resources within himself to meet with and overcome difficulties in all the various stages of the proceeding."

Stricture. In the treatment of stricture of the urethra, all armed bougies have been laid aside, in favour of the plain metallic catheter and bougie. The milder cases are easily overcome. A plated steel bougie, selected of such a size as will with no great difficulty pass the constricted part, is gently insinuated along the urethra. After three or four days, the introduction is repeated. Then at each farther re-introduction, at an interval of a few days, the size of the instrument is gradually increased, until it completely fills the orifice; a sign that sufficient distention of the canal has been achieved. After this, it is right to pass the last instrument occasionally, at long intervals, to counteract any tendency towards return of the contraction. Soft pliable bougies may sometimes be useful for mere exploration of the canal, but are not of much use otherwise; it being difficult to guide their points, or ascertain the exact direction which they assume. During the cure, the state of the urine should be strictly attended to; for its acridity—one

of the causes of stricture—may, by irritation of the urethra, materially retard the progress. Should the bougie cause serious irritation of the urethra, as sometimes happens, the interval between its introductions must be increased, allowing the painful effects of each to subside before another is attempted, else much more harm than good will accrue from the use of the instrument. For the penetration of tight unyielding strictures, a firm silver catheter is the most appropriate instrument, its size being proportioned to the extent of contraction. For very obvious reasons, great caution must be observed in its use; steady, cautious, patient, and gentle pressure, in the right direction, must never be superseded by sudden and daring force, or irreparable mischief may ensue. "Lightness of hand, and gentleness of manipulation, will often enable a surgeon to overcome difficulties which to others may have proved insuperable. The operation of introducing a catheter through what has been called an impermeable stricture, is without doubt the most difficult in the whole range of surgical practice, and demands all the prudence, science, and skill of a master. The art can only be acquired, and that gradually, by frequent practice." When the stricture is very tight, and has afforded much opposition to the passage of the catheter, and more particularly when the operation has been undertaken on account of retention of urine, it is well to retain the instrument secured in the strictured part for twenty-four or eight and forty hours. The cure is thus much expedited, as well as recurrence of the retention prevented. The presence of the foreign body in the stricture calls up a natural effort for its extrusion, resulting in relaxation of the part, with profuse discharge; and so remarkable is the dilatation thus effected, that on withdrawing the instrument at the end of the time already specified, it is found "lying quite loose" in the passage, although at its introduction it had been grasped most tightly, and firmly fixed in the stricture. Immediately after its withdrawal, a much larger instrument can usually be introduced with ease, and the cure is then proceeded with as in ordinary cases. Sometimes the parts so strenuously resist the presence of the foreign body, that it is prudent to remove the instrument in less time than we have mentioned. Under no circumstances should it be retained beyond two days. It becomes coated with calculous deposit; and, besides, there is danger of its irritation proving excessive; ulceration may take place in the urethra, or abscess form along its course.

Thus the worst possible stricture may be overcome, and the urethra restored to its healthy functions and dimensions. But, as already said, prudence and experience are inseparable from the safe use of the small catheter; with them, it is a most valuable instrument, and saves many a patient now-a-days who would otherwise have become the victim of cruel and dangerous operation. It is seldom, indeed, that we now hear of puncture of the bladder, even by the rectum, a proceeding at one time so common here, as to be known as "the Edinburgh operation." And we as seldom hear of the catheter producing tears and wounds of the urethra, followed by abscess and fistula, or urinary infiltration ending in the death of the patient, or at least in the destruction of a large portion of his genital integument and cellular tissue. When from any cause urine has escaped into the cellular tissue of the perineum, free and deep incision, so as to afford ready escape to the poisonous fluid, cannot be too early resorted to. Should it happen that the surgeon, notwithstanding skill and perseverance, is foiled in passing the catheter, and relieving distention, then, instead of puncturing the bladder, the preferable procedure is to "make a free opening in the perineum, directly upon the obstructed part; to cut upon the end of the catheter, carrying the knife forwards; to open the dilated portion of the urethra, and then to pass the catheter on to the bladder." Thus the viscus is relieved, and a sure commence-

Surgery. ment made of the cure of the stricture, while no permanent inconvenience ensues, as after puncture of any part of the bladder. In passing the catheter to relieve retention caused by prostatic disease, it should never be forgotten that the urethra is in such cases much elongated, and that in consequence the instrument ought to be three or four inches longer than those in ordinary use. The treatment of the enlargement of that gland is entirely palliative; nor can proposals for its removal by operation be ranked among the modern improvements.

Diseases and injuries of the windpipe. Diseases and injuries of the windpipe are better understood, and more successfully treated, than formerly. In the latter, the surgeon is less meddlesome, and his patient is benefited accordingly. In wounds of the throat it was formerly the custom, after having secured the larger arterial branches, to proceed at once to closure of the wound, dragging it together by stitches and plasters, and covering all by lint and bandage, as if the principal object were to conceal the horrid gash from view. The consequence was, that the blood which continued to ooze, finding no ready outlet externally, collected in the air-passages, and suffocated the patient, provided, as was most probable, he had not at the time sufficient energy for forcible expectoration; or if this danger was escaped, it was shortly succeeded by one equally imminent, closure of the windpipe at the injured part, from inflammatory swelling of the wound. Now the intelligent surgeon is less precipitate; he knows the danger of the old system, and avoids it by treating cut throat on the same principles as he would an ordinary wound, making no approximation until all oozing has ceased, and then only drawing together the corners, trusting the centre to the more gentle apposition by bending the head forward, and by bandage retaining the chin approximated to the top of the sternum. Thus a free outlet is left to the discharges which must form; for the transverse nature of the wound, and the constant motion of its edges in respiration and deglutition, render union by the first intention impossible. Immediate risks are thus avoided; and if the patient's energy prove sufficient, the wound will gradually close by granulation. But in general, at least in attempted suicides, a low fever ensues, against which all efforts toward cure are unavailing. The patient should be kept in a comfortably warm and equable temperature, and the fore part of the neck should be protected by some loose covering, that the inspired air may be, as nearly as possible, of the same temperature as in natural respiration. Thus the occurrence of bronchitis is so far obviated; and so long as air passes through the wound, no other dressing need be applied. When the pharynx is involved in the wound, nourishment is given from time to time through a tube introduced by the mouth; not through the wound, lest contraction of the tracheal opening should be interfered with, and its edges cicatrize separately, leaving the patient in a very miserable plight. Sometimes respiration becomes obstructed by swelling of the mucous membrane and accumulation of viscid mucus, so as to endanger suffocation, and render it necessary to open the windpipe longitudinally below the obstructed part. In injuries of the interior of the throat, tracheotomy is also sometimes necessary. When the glottis has been injured, for example, by the swallowing of acids, or hot water, or by the inhalation of steam, should the ordinary active treatment fail to arrest the urgent symptoms, tracheotomy must be had recourse to without delay, otherwise the patient will perish, either by immediate suffocation, or by effusion consequent on imperfect pulmonary circulation. A simple blow on the larynx may so completely paralyze the parts, as to render opening of the windpipe necessary for restoring the

respiration. And the operation is also required when foreign bodies have lodged in the air-passages, and cannot be expelled by expectoration. If allowed to remain, they are productive of the greatest annoyance; perhaps suffocation is immediate; and if they do not speedily induce inflammatory action of the most serious nature, they are certain ultimately to occasion phthisis, or other chronic disease of fatal tendency. If the foreign body is loose, it will be spontaneously ejected from the opening; if fixed, it must be dislodged by forceps.¹

In diseases of the air-passages, tracheotomy often becomes necessary, on account of obstruction at the top of the windpipe preventing free entrance of air into the lungs. In acute inflammatory affections, croup, for example, it is seldom admissible. In the early stage, "whilst active antiphlogistic remedies are indicated, and considered likely to afford relief, it could not with propriety be proposed; in the latter stages, after lymph has formed, when the lungs are gorged, and effusion has commenced at the base of the brain, no good purpose can be answered by an operation." Sometimes, in adults, a favourable opportunity for the operation may be selected between these stages, but it is seldom. To the chronic affections the operation is more applicable. Even in phthisis laryngea, the most intractable of these, advantage may be derived from it when performed at an early period; the diseased parts above the opening are set at rest, and an opportunity is afforded of making direct application, through the wound, of the suitable remedies to the ulcerated surface. But it is in cedema of the glottis, whether as a primary affection, or supervening on previous disease, that its beneficial results are most frequent and most apparent; the patient is at once relieved from impending suffocation; the swollen parts are put to rest, and in time subside; and after a while they so far recover their healthy condition, as to admit of closure of the wound and re-establishment of the natural course of respiration. In all cases where opening of the windpipe is required, whether on account of accident or disease, tracheotomy is preferable to laryngotomy, and though a little more difficult, is equally safe in performance. An opening in the cricoid membrane will not always suffice for detection and removal of a foreign body; and being placed in the ordinary site of laryngeal disease, will usually fail to afford relief when undertaken on that account. The incisions in tracheotomy are made very carefully, so that stray vessels may be pushed aside in safety; the trachea is pierced during the act of deglutition, when the larynx is elevated and the windpipe elongated; a silver tube is immediately introduced, of calibre proportioned to the object in view, and of such a form as to prevent oozing from the wound by compression of the edges. After a short time all irritation from the presence of the tube ceases; but during the whole cure great attention must be paid that it be kept clear of the vitiated mucus. It should also be protected by some loose covering, in the same manner and for like reasons as in cases of cut throat. In the treatment of all affections of the throat, the possibility of tracheotomy becoming requisite should always be kept in view; and the curative applications should consequently be confined as much as possible to the sides of the neck, leaving the fore part free, otherwise much difficulty may be thrown in the way of the operator.

The treatment of diseases of the rectum has become simplified and improved along with the rest of surgery. "Many attempts have been made to mystify the subject of diseases of this region, and to separate them in a great measure from general surgery. There is no such difficulty as has been supposed in understanding their nature; the principles

¹ A most interesting case of foreign body in the bronchus, successfully removed by operation, is detailed by Mr Liston, in his *Practical Surgery*, p. 371.

Surgery. which should guide their management are simple, and the means, operative and otherwise, easily enough applied." Of late a variance of opinion has arisen in regard to the treatment after operation on the rectum; one party maintaining that in all cases little or no dressing is required; the other, that in every case stuffing and compression of the wound are essential to the safety of the patient. As is usual when opinions are in extreme opposition, we find that truth occupies a middle place. In some slight cases of operation, for fistula, hæmorrhoids, &c., no more dressing is required than what is sufficient to prevent immediate union of the divided parts; while in others, a degree of compression must be made on the divided surface, proportioned to the extent of the incision and the probability of hæmorrhage. It would be very unnecessary to cram the wound in the first class of cases; in the second, it would be equally unwise to leave the parts wholly unsupported.

Tumours. As the pathology of tumours has become more and more understood, operative procedure has been withdrawn from some and extended to others. Diagnosis having become both more easy and more accurate, we can now readily distinguish between those of a benign and those of a malignant disposition. In regard to the latter, experience has taught us to forbear from operative interference, unless at the very first accession of the disease; for though the more simple tumours, even when of large size and long duration, may be removed with every prospect of permanent cure, yet in those of a malignant nature, immunity from recurrence of the disease can be hoped for only when the removal is very early; when the local affection is still limited and loosely attached; when there is a certainty of being able to remove, not only the morbid structure itself, but some portion of the unaltered tissues which invest it; before any affection of the neighbouring lymphatics can be detected; and before the general system seems to have been permanently involved. Among the more benign tumours, the most remarkable extension of active surgery is in regard to the solid tumours of the jaw. Not long since these formidable formations were looked upon with horror and dread, as one and all of the most malignant tendency, and were consequently left to their own course. But now we have been taught that such is not, and ought not to be, the case; that many doubtless are most malignant, and must not be interfered with; but that others, and sometimes even those of the most formidable appearance, are sufficiently local and apathetic to warrant the adoption of active interference with the most sanguine hopes of success. Both the upper and lower jaws, involved in large and frightful tumours, have of late years been removed by operation; and when the case has been judiciously selected, good success has been invariable. In the soft medullary tumour of the upper jaw, commencing in the antrum, an opportunity warranting interference can seldom occur; for before the morbid formation has appeared externally in the mouth or nose, it has not only completely involved the bone in which it originated, but also included in the diseased mass the palate-bone, the ethmoidal cells, the orbit, and even the sphenoidal sinuses.¹ It is only when such a disease, at an early period of its existence, is confined to the antrum, that removal of the superior maxillary bone can be of service; but unfortunately its true nature is seldom discovered until a portion of the tumour has become apparent by the giving way of the parietes; and when that has occurred the case is hopeless, for its extension backwards very far exceeds the outward protrusion. In its first stage the prominence of the cheek has the same smooth glistening appearance as in chronic

abscess of the antrum; but the parietes of the tumour are hard and unyielding; they soon thin at one or more points, there communicating a pulpy feeling to the finger; and when they have completely given way, the ravages of the disease are as rapid as uncontrollable. The more benign tumour in this situation—originating in the bone, and usually the result of injury—is, on the contrary, slow in its progress and of very firm consistence; its surface is lobulated, and if ulcerated by accident, soon heals again; the internal structure, of a firm fibrous character, is limited by a dense cellular cyst; and the neighbouring bones are either simply displaced, or removed more or less by interstitial absorption; the progress of the tumour is in consequence almost entirely towards the surface. It is in such cases that the surgeon does not now hesitate to remove the superior maxillary bone; for with it he knows that he can take the whole diseased formation. It is doubtless a formidable operation, and not unattended with danger; but the risk is insignificant when compared with the ultimate benefit likely to accrue. It is therefore evidently of the highest importance to distinguish accurately these two classes of tumour, the treatment suitable to each being so widely different; in the one case operation is wholly inadmissible, while in the other the sooner it is had recourse to, the greater is the probability of a successful result. Care should also be taken not to confound either with the more simple affection of accumulated fluid in the enlarged antrum; for it has happened that a surgeon, after having made up his mind to attempt removal of the superior maxilla, has, "on trying to divide the connections of that bone, had his hands covered with purulent matter, and himself with shame and confusion." The same general description applies to tumours of the lower jaw as to those of the upper, with this difference, that the relative position of the former somewhat prolongs the favourable opportunity at which tumours even of malignant tendency may be removed. The medullary tumours are also of much less frequent occurrence; there is no large cavity, like the antrum, in which they may originate, and the great majority consequently come under the denomination of osteo-sarcoma. That very many tumours of the jaws are attributable to disease, or even faulty position, of the teeth, and to unskilful dental operations, is a fact as true as it is important, and should direct both surgeon and patient to greater and more frequent attention to those influential little portions of the osseous system. After the operation on either jaw, an unseemly void of course remains; but nature, assisted occasionally by the dentist, does wonders in repairing this, and the actual deformity is in many cases surprisingly slight.²

In operations for the removal of tumours in the soft parts, we have elsewhere stated that the incisions should be so planned as to divide the principal vessels at the outset, as thus both time and blood are saved. If the vessels implicated are large, temporary pressure on the trunk may be made by the assistant; but it can seldom if ever be necessary to practise a preliminary operation for the securing of that trunk by ligature. In most cases the dissection of the tumour should be made as rapidly as is consistent with the safety of important parts in the neighbourhood. But when the tumour is suspected of a malignant tendency, the duration of the proceeding must not be considered; the dissection must be methodical and deliberate. As it proceeds, the parts must be examined carefully by both the finger and eye; and on its completion, the removed mass must be minutely surveyed, lest any shred of morbid formation be left in the wound. No successful result can be hoped for, un-

¹ Sometimes these tumours commence in the latter situations, and involve the superior maxillary bone secondarily.

² For details of the operation, we again refer to Liston's Practical Surgery; a work of great value, from the perusal of which both practitioner and student will derive much profit, and to which, we beg to acknowledge, we have been not a little indebted in the course of the present article.

Surgery. less the whole altered structure is completely and freely removed. Another point in regard to operations on tumours ought never to be forgotten, namely, that the most simple and best dispositioned formations may, in the course of time, degenerate into the most malignant and intractable, and therefore should not be exposed to this contingency; they should be early removed, for the merest steatom has, by circumstances, been transformed into the most frightful and deadly fungus.

Vascular tumours, of erectile tissue, are now safely and efficiently removed by ligature. Formerly they were usually left undisturbed. Sometimes attempts at excision were made, but the results were truly discouraging, the hæmorrhage proving most alarming, and not unfrequently fatal. In a mere nævus, obliteration of the vessels may be safely effected by vaccination, pressure, acupuncture, seton, or the application of escharotics. But such treatment is totally inapplicable to the erectile tumours. These, when very small, may be removed by excision; but it is not a safe proceeding, particularly in young patients, to whom loss of blood is of serious consequence. But by ligature, vascular tumours of almost any size and extent are safely removed, by arresting their circulation, and so producing sphacelus of the adventitious structure. When the formation is of a broad base, several ligatures are required, passed beneath the tumour by needles; and when the integument is free, or but slightly involved, it should be reflected by preliminary incision, so that these ligatures may be the more effectually applied. By such procedure, even enlargement of the thyroid gland may be removed. Of course no one would think of attacking the whole tumour on account of the mere deformity; but it sometimes happens that enlargement of the isthmus occasions difficult respiration, congestion of the cerebral vessels, and other alarming symptoms; and in such cases the offending part has been successfully removed by a combination of incision with ligature, using the knife as deeply as the hæmorrhage will permit, and then completing the isolation of the lobe by strong ligatures applied by transfixion.

Venereal disease.

In the treatment of venereal affections, mercurial supremacy has gradually given way to the influence of common sense, and the disease has consequently become more mild and tractable, particularly in its secondary forms. The primary symptoms are treated as simply local affections, until circumstances prove the contrary, which will be comparatively seldom. When the exhibition of mercury seems advisable, little usually suffices; it is used, not abused as formerly.

Hydrocele.

Hydrocele, which was at one time the apology for very severe surgical proceedings, by knife, setons, and escharotics, is now under very simple treatment; the palliative, is mere tapping of the cavity; the permanent, injection of it, after tapping, by some gently stimulating fluid, port wine, for example. But great care must be taken during injection, that none of the fluid enter the cellular tissue of the scrotum, otherwise most violent inflammatory action must ensue in the infiltrated parts.

Restorative surgery.
The nose.

Restorative surgery, in former years scarcely attempted, is now making rapid progress towards perfection. Noses are made and repaired most adroitly, not according to the old inconvenient system of the European father of rhinoplastics, but by a modification of the plan practised by the Koomas, a caste of Hindoos, and first introduced into this country by Mr Carpue. This decorative operation has been very successfully practised by Mr Liston, who is the author of an important change in the procedure—not bringing the columna from the forehead, but waiting till the new apex and alæ so obtained are consolidated, and then fashioning

a column out of the upper lip.¹ By this little operation a more vigorous and substantial support is obtained for the new parts; and, besides, the lip, which formerly hung tumid and pendulous, is at the same time very much improved in appearance. His nasal constructions, he tells us, are scarcely to be distinguished from the natural feature at a little distance, are quite sufficient for the ordinary uses of that organ, and sometimes have been brought to desiderate and enjoy the questionable accomplishment of snuff-taking. He has likewise been very successful in relieving the nose from inconvenient and unseemly encumbrances, produced by lipomatous enlargement of the integument. The excrescence is simply pared off, care being taken not to interfere with the subjacent cartilages. The raw surface usually cicatrizes rapidly, leaving the feature of its natural form and size. By an operation conducted on similar principles as the rhinoplastic, the lower lip is renewed from beneath the chin; the ear, or rather portions of it, from the integument behind; and deficiencies in the urethra can be closed by adaptation of a portion of either the prepuce or loose neighbouring integument. Such proceedings some may affect to disregard as trivial; but they are not looked upon as such by the unfortunate individuals to whom they are applicable, and really constitute a most interesting and useful department of operative surgery.

Harelip. Harelip, one of the most disagreeable of the congenital deficiencies, can be very perfectly remedied, by paring the edges of the fissure, and securing them in close and accurate apposition by two or more points of twisted suture. According to the principles already detailed, no further dressing is applied; and if the patient be otherwise in good health, and the parts protected from external injury, adhesion will seldom or never fail to occur. The most important part of the operation, as regards restoration of the lip's natural appearance, is complete removal, by the paring of the rounded margins where the membrane that covers the edge of the fissure joins the true prolabium. If this be not attended to, the operation is imperfect, for a most unseemly notch remains in the lip; in fact, the fissure is merely diminished, not obliterated. But when these rounded portions are completely removed, and the operation is in other respects well conducted, a mere line of cicatrization is all that remains of the deformity.

Club-foot. Club-foot, a most inconvenient as well as unseemly malformation, is remedied in children by simple means; merely applying the necessary retentive apparatus, until the parts become fixed in the normal position in which that apparatus places them. Now, the cure is extended even to the adult; and very many varous feet, formerly regarded as irremediable, are restored to usefulness and symmetry, at the cost of but slight pain and inconvenience. The first part of the treatment is to sever the tendo Achillis; an operation simple in performance, and seldom if ever followed by any untoward results. A narrow knife or lancet-shaped needle is introduced obliquely through the integument, beneath the tendon, and at a little distance from it on one side; "by directing the edge against the resisting fibres, the foot being kept powerfully extended by an assistant, the object can be effected with scarcely a perceptible external wound, and with the escape of only a drop or two of blood." The foot is then placed in the desired position, and retained so by the suitable apparatus, for the necessary period; the foot becomes both "useful and ornamental;" and the space between the separated ends of the divided tendon is, after no long time, firmly and completely occupied by a new formation, of tendinous structure and capabilities, by means of which the functions of the muscles are ultimately restored.

¹ The columnar slip includes the whole thickness of the lip, and in its application is not twisted. The mucous membrane, after exposure in its new situation, soon becomes cuticular in both appearance and function.

Surname. A similar operation has been for some time in practice in the veterinary profession. It was first performed on the human body by the continental surgeons. After dividing the tendon, they again brought the retracted ends together, and retained them in apposition until partial reunion took place, when, by gradual extension, the new formation was elongated to the extent necessary for the adjustment of the foot. This method, however, is both more tedious and more painful than the one already described; and by either, the repair is equally substantial and efficient. In some cases of the deformity, the bones are either so deficient in original development, or so firmly secured in their malposition, as to be irremediable even by such means. But, as already stated, there are very many cases, both of simple extension of the

foot, and of that complicated with inversion, in which this little operation, well seconded by the care of the machinist, will be followed with success almost equal to the most sanguine hopes of both surgeon and patient.

We have thus briefly sketched the subjects which naturally occur to us, as the most prominent examples of the modern advancement of surgery. It were easy to swell the list. But our assigned limits have already been attained, if not exceeded; and enough has probably been said, both to convey a general idea of the improvement recently effected in this profession, and to encourage a hope that such progress will still continue, year after year, bringing the practice of this useful, enlightened, and noble art, closer to perfection. (c. D.)

SURINAM. See **GUIANA**.

SURNAME, that which is added to the proper name, for distinguishing persons and families. It signifies some name superadded to the proper name to distinguish the individual, as Artaxerxes *Longimanus*, Harold *Harefoot*, Malcolm *Canmore*. Surnames were introduced among all nations at an early period, and seem to have been formed at first by adding the name of the father to that of the son. This was the practice among the Hebrews, as appears from the Scriptures. Caleb is denominated the son of Jephunneh, and Joshua the son of Nun. That the same thing was customary among the Greeks, every one who has read the poems of Homer must remember. We have an instance of it in the very first line of the *Iliad*: Πηληϊάδεω Ἀχιλλῆος, "Achilles the son of Peleus." This is perhaps the general origin of surnames, for it has been common among most nations.

The Romans generally had three names. The first, called *prænomen*, answered to our Christian name, and was intended to distinguish the individuals of the same family; the second, called *nomen*, corresponded to the word *clan* in Scotland, and was given to all those who were sprung from the same stock; the third, called *cognomen*, expressed the particular branch of the tribe or clan from which an individual was sprung. Thus, in Publius Cornelius Scipio, *Publius* corresponded to our names John, Robert, William; *Cornelius* was the name of the clan or tribe, as Campbell was formerly the name of all the duke of Argyle's clients, and Douglas the name of the retainers of the duke of Hamilton's progenitors. *Scipio* being added, conveyed this information, that Publius, who was of the tribe of the Cornelii, was of the family of the Scipios, one of the branches or families into which that tribe was divided. Respecting the three names which were common among the Romans, we may say that the first was a name and the other two were surnames.

Du Chesne observes, that surnames were unknown in France before the year 987, when the lords began to assume the names of their demesnes. Camden relates, that they were first assumed in England a little before the conquest, under King Edward the Confessor; but he adds, they were never fully established among the common people till the time of Edward II.: till then they varied with the father's name. Thus, if the father was called *Richard*, or *Roger*, the son was called *Richardson*, or *Hodgson*. The oldest surnames are those which we find in Domesday-Book, most of them taken from places, with the addition of *de*; as Godefridus *de Mannevilla*, Walterus *de Vernon*, Robert *d' Oyly*, &c.; others from their fathers, with *filius*, as Gulielmus *filius Osborni*; others from their offices, as Eudo *Dapifer*, Gulielmus *Camerarius*, Gislebertus *Cocus*. But the inferior people are merely noted by their Christian names.

Surnames seem to have been introduced into Scotland, in the time of William the Conqueror, by the English who

accompanied Edgar Atheling when he fled into that kingdom. These had their proper surnames, as Moubray, Lovell, Lisle, using the particle *de* before them; which makes it probable that these surnames had been derived from the lands which their ancestors or they themselves had possessed. In Kenneth II.'s time, about the year 800, the great men had indeed begun to call their lands by their own names; but the ordinary distinctions then used were only personal, and did not descend to succeeding generations, such as those employed by the Hebrews and Greeks: for example, *John the son of William*; or the names of office, as *Stewart*; or accidental distinctions from complexion or station, *Black*, *White*, *Long*, *Short*; or the name of their trade, as *Weaver*, *Tailor*, *Baxter*, *Brewster*.

It was long before any surnames were used in Wales, except that of son, as Evan ap Rice, Evan the son of Rice; Evan ap Howel, Evan the son of Howel. But many of them have at length formed separate surnames, as the English and Scottish, by leaving out the *a* in *ap*, and joining the *p* to the father's name: thus Evan ap Rice becomes Evan Price; Evan ap Howel, Evan Powel.

When we come to inquire into the etymology of surnames, we must allow that many of them were originally significant of the qualities of mind, as *Bold*, *Hardy*, *Meek*; some of the qualities of body, as *Strong*, *Low*, *Short*; others expressive of the trade or employment followed by the persons to whom they were applied, as *Baker*, *Smith*, *Wright*, *Butler*, *Page*, *Marshall*. But the greatest number, at least of the ancient surnames, were borrowed from the names of places. Camden avers that there is not a village in Normandy but has given its name to some family in England. He mentions as examples, *Percy*, *Devereux*, *Tankerville*, *Mortimer*, *Warren*, &c. They were introduced with William the Conqueror. Several have been derived from places in the Netherlands, as *Gaunt*, *Tournay*, *Grandison*; and many from the names of towns and villages in England and Scotland, as *Wentworth*, *Markham*, *Murray*, *Aberdeen*. Many have been formed from the names of animals, as quadrupeds, birds, fishes; from vegetables, and parts of vegetables, as trees, shrubs, flowers, and fruits; from minerals of different kinds. Others are formed from such a variety of accidents that it is impossible to particularize them.

SURPLICE, the habit of the officiating clergy in the Church of England. By Can. 58, every minister saying the public prayers, or ministering the sacrament or other rites of the church, shall wear a decent and comely surplice with sleeves, to be provided at the charge of the parish. But by 1 Eliz. c. 2, and 13 and 14 Car. II., the garb prescribed by act of parliament, in the second year of King Edward VI. is enjoined; and this requires, that in the saying or singing of matins, and even songs, baptizing and burying, the minister in parish churches and chapels shall use a surplice. And in all cathedral churches and colleges, the archdeacon, dean, provosts, masters, prebendaries, and

Surrey. fellows, being graduates, may use in the choir, besides their surplices, such hoods as pertain to their several degrees; but in all other places every minister shall be at liberty to use a surplice or not. And hence, in marrying, churching of women, and other offices not specified in this rubric, and even in the administration of the holy communion, it seems that a surplice is not necessary. Indeed for the holy communion the rubric appoints a white alb plain, which differs from the surplice in being close-sleeved, with a vestment or cope.

Boundaries and extent.

SURREY, an inland English county, on the banks of the Thames, by which, on its northern side, it is separated from Middlesex. On the west it is bounded by Berkshire and Hampshire, on the south by Sussex, and on the east by Kent. Its shape is an oblong, of moderate regularity, except on its northern side, where considerable indentations are formed by the curvatures of the Thames. Its length from east to west is about thirty-seven miles, and its breadth from north to south about twenty-five. The area is 758 square miles, or 485,120 statute acres.

Population.

The population of this county at the four decennial periods of enumeration was found to be as follows; viz. in 1801 it amounted to 269,043, in 1811 to 323,851, in 1821 to 398,658, and in 1831 to 485,700.

At the last date the occupiers of land employing labourers were..... 1,873
Occupiers of land not employing labourers..... 727
Labourers employed in agriculture..... 16,761
Labourers employed in manufactures..... 2,065
Labourers in retail trade and handicraft..... 44,139
Capitalists, bankers, &c..... 14,235
Labourers not agricultural..... 24,878
Males at and above twenty years..... 10,756
Male servants..... 6,232
Female servants..... 24,540

In the same year the number of families chiefly employed in agriculture was found to be 14,647; of those chiefly employed in trade, manufactures, and handicraft, 49,616; and of those not comprised in either of the preceding classes, 44,814. The number of inhabited houses was 80,070, occupied by 109,077 families; of uninhabited, 6102; and of those building, 1073.

The amount of the annual value of the real property of the county, as assessed for the purposes of the property-tax in 1813, was L.1,579,173.

Towns and villages.

The towns and villages within this county, whose inhabitants exceed 3000, are, with their population in 1831, as follows. Such of them which are so in contact with the metropolis as to form suburbs to it, are here distinguished by an asterisk.

*Southwark.....	91,501	Farnham.....	5,858
*Lambeth.....	87,856	Battersea.....	5,540
*Newington.....	44,526	Streatham.....	5,068
*Bermondsey.....	29,741	Chertsey.....	4,795
Camberwell.....	28,231	Dorking.....	4,711
*Rotherhithe.....	12,875	Godalming.....	4,529
Croydon.....	12,447	Mitcham.....	4,387
Clapham.....	9,958	Egham.....	4,203
Kingston.....	7,257	Guildford.....	3,813
Richmond.....	7,243	Putney.....	3,811
Wandsworth.....	6,879	Ryegate.....	3,397

Face of the country.

The face of the country exhibits great varieties. On the north, by the banks of the Thames, from Lambeth to Egham, the richness of the highly improved country, the abundance of trees, the verdure of the meadows, the undulation of the hills, with the numerous elegant private houses, all display the most pleasing marks of taste, wealth, and comfort. The centre of the county is a range of chalk hills, much covered with thick underwood, intermixed with arable fields badly cultivated, and utterly destitute of water. The south part, at the foot of this range of hills, is a

flat clayey country, nearly impassable in the winter, but covered with some of the best and largest oak trees that are to be found in the island. The north-western part exhibits a considerable tract of the most sterile black heaths, while on the south-west, near Farnham, is some of the most productive land in England.

The productions of agriculture are various, and, at a distance from the capital, scarcely differ from those of other districts in similar circumstances. A greater proportion of clover and of sanfoin is cultivated on the hills, where there are no natural meadows, than in most other parts of the kingdom. Woad is also very extensively raised in the same districts. It is commonly sown along with turnips intended for feeding sheep, which will not touch woad. It is generally harvested before the corn-crops are ready for the sickle. Near London, the garden-ground extends over several thousand acres. The growing of plants, for the use of the druggists and perfumers, engages much attention; and those gardens supply peppermint, lavender, wormwood, chamomile, aniseed, liquorice, poppy, and other similar articles. Hops are extensively cultivated near Farnham, and are sold for higher prices than those of any other districts.

No minerals are now raised in the county; for though iron is known to exist, and was formerly worked with charcoal, the improvements in chemistry have fixed that operation to the coal-districts. The fossil riches are valuable, especially fullers' earth, which is of the best quality, and in abundance, and supplies the cloth manufacturers both in the west and north of England. Limestone is plentiful; and that, as well as chalk, is converted into lime, upon a great scale, for the use of the builders of the metropolis. The quarries of Merstham produce an excellent fire-stone; and the sand near Dorking and Ryegate is in great request for making glass, hour-glasses, and other purposes.

The manufactures are various and extensive; but, being almost exclusively near the metropolis, may more properly be considered as belonging to London than to the county of Surrey. The principal of these are breweries and distilleries on a magnificent scale. The tanners, rope and sail-makers, glass-makers, starch and hair-powder makers, and the preparers of vinegar and raisin wines, carry on large trades. A few miles farther from London, chiefly on the banks of the river Wandle, the calico-printers and bleachers have large establishments.

All the rivers of this county empty themselves into the Thames. The only navigable river, besides that fine stream which bounds it, is the Wey, on which barges pass above Guildford into the Basingstoke Canal. The Mole is a beautiful small stream, celebrated for sinking into the ground, and at some few miles lower again emerging. The Wandle runs a short course, but is of great value, from the vast quantity of mill-machinery which it keeps in motion, and the employment which it thus affords to several thousand persons. It rises in one spring near Croydon, turns a large mill within a few yards of its source, and runs nine miles before it joins the Thames. The Medway rises in Surrey, but is a very small stream till it enters the county of Kent. The Loddon, a small river on the western border, is chiefly valuable for the supply of water which it affords to the Basingstoke Canal. That canal was one of the first executed in this part of the kingdom, having been finished in 1796. The Croydon Canal only reaches that town from the Thames; and the little success attending it has prevented its being carried farther, as was originally intended. The Surrey Canal runs parallel to the Thames; but, by avoiding the sinuosities of that river, and the whole of the metropolis, is expected to be beneficial to the inhabitants on the upper banks, by conveying coals and other heavy commodities to them, from ships, at a cheap rate. Its entrance, from the Thames below London Bridge, has a fine basin, capable of containing 100 sail of square-rigged ves-

Surrey.

Minerals and fossils.

Manufactures.

Rivers, canals, and railroads.

Surrey. sels. Railroads have been constructed from Merstham to the Thames; but the project has not repaid those who have advanced the capital a sufficient interest to recommend any further attempts. Several railroads which will pass through the county have been projected, and acts of the legislature for some of them have been obtained: only one of them has yet made much progress, namely, the London and Southampton. Some obstacles long delayed that intended to proceed to Brighton, and the same is the case with the one projected from London to Dover.

Antiquities
and inter-
esting ob-
jects.

Among the Roman antiquities of this county are the Ermine Way, which traversed it, and the remains of which may still be traced near Dorking. The piles are still standing in the river Thames at Walton, which were placed there by the ancient Britons, to impede the passage of Julius Cæsar. The vestiges of the encampments of the Romans may be distinctly traced at Bottlehill, at Waltonhill, and some other spots. Among the antiquities of later date, are the Palace of Lambeth, belonging to the see of Canterbury; that of Farnham, belonging to the see of Winchester; the remains of the Abbey at Croydon, the Castle of Guildford, Waverley Abbey, and some other Saxon edifices. The meadow of Runnymede, St Anne's Hill, the seat of the late Mr Fox, the park of Richmond, and the terrace there, with the palace and gardens of Kew, are all objects that excite a high degree of interest. It is difficult to determine which of the towns is the capital of the county. The principal prison is in the borough of Southwark, and the quarter-sessions are held there; but the lent assizes are held at Kingston-on-Thames, and the summer assizes alternately at Croydon and at Guildford.

Capital.

Titles and
represent-
ation.

The titles derived from this county are those of the Duke of Richmond, the Earls of Surrey, Guildford, and Onslow, and Baron Abinger. The county is formed into the eastern and western division to elect two members for each. The election for the east division is held at Croydon; and the other

polling places are Ryegate, Camberwell, and Kingston. The western election is held at Guildford; and the other polling places are Dorking and Chertsey. The boroughs of Gatton and Haselmere, which formerly returned two members each, have been disfranchised; and Ryegate, which chose two, now elects but one member. Lambeth has been erected into a borough, and returns two members; as do the ancient boroughs of Southwark and Guildford.

The number of seats belonging to noblemen and gentle-^{Chief} men in this county is so great as to forbid the noticing of seats. even all those which in any other county would be deemed highly worthy of notice. The most remarkable are, her majesty's palace of Kew; Claremont, king of Belgium; Clandon Place, earl of Onslow; Pepper Harrow, Lord Middleton; Oatlands, Lord Francis Egerton; Painshill, Lord Carhampton; Ockham Park, earl of Lovelace; Addington Palace, archbishop of Canterbury; Rooksnest, C. H. Turner, Esq.; Nonsuch Park, S. Farmer, Esq.; Gatton, Lord Monson; Nork House, Lord Arden; Betchworth, Right Honourable H. Goulbourne; Norbury Park, Joseph Dennison, Esq.

See Manning and Bray's History of Surrey; Salmon's Antiquities of Surrey; Stevenson's View of the Agriculture of Surrey; Lyson's Environs of London.

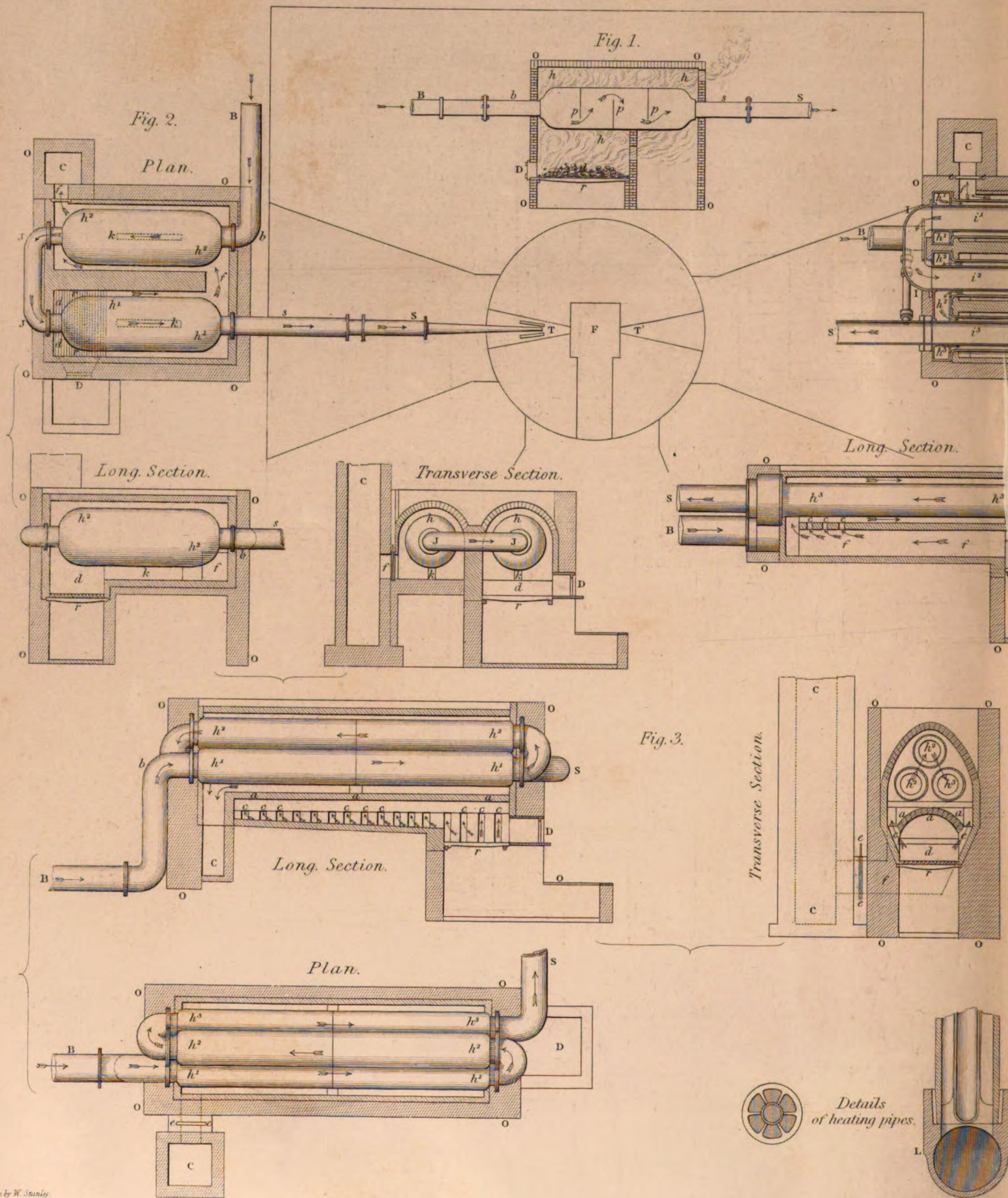
SURROOL, a town of Bengal, district of Birbhoom, where the East India Company have a factory for white cottons. Long. 87. 42. E. Lat. 23. 39. N.

SURSOLID, or **SURDESOLID**, in *Arithmetic*, the fifth power of a number, or the fourth multiplication of any number, considered as a root.

SURSUTTY, a river of Hindustan, which rises in the mountains on the north-east boundary of the province of Delhi, and running south-west, is lost in the sands of Ajmeer. A town and fortress of the same name is situated on the western bank of this river, and now belongs to an independent chief. Long. 75. 27. E. Lat. 29. 13. N.

Surrool
||
Sursutty.

END OF VOLUME TWENTIETH.



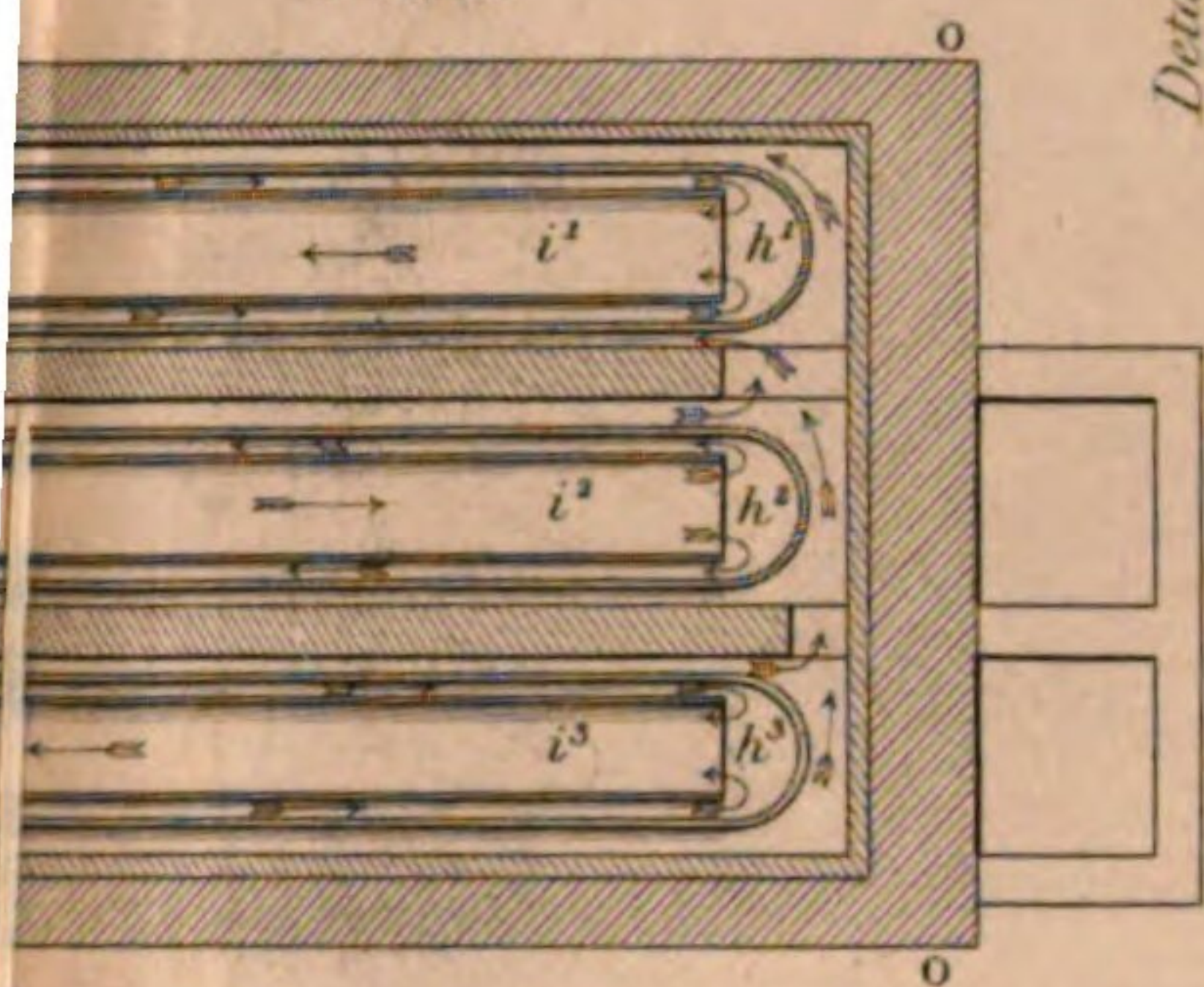
IRON BY HOT BLAST.

Fig. 6.

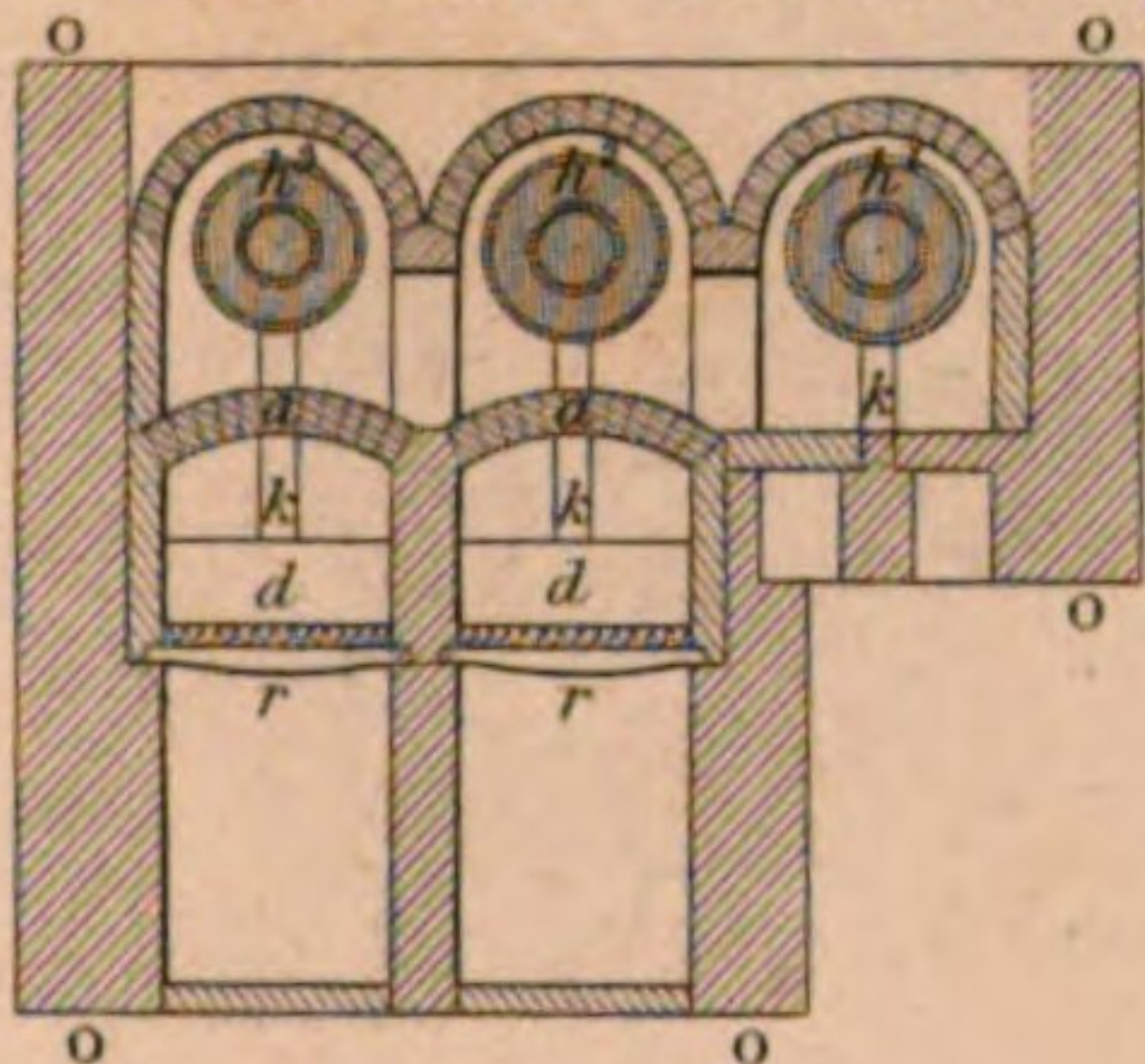
Fig. 4.

Plan.

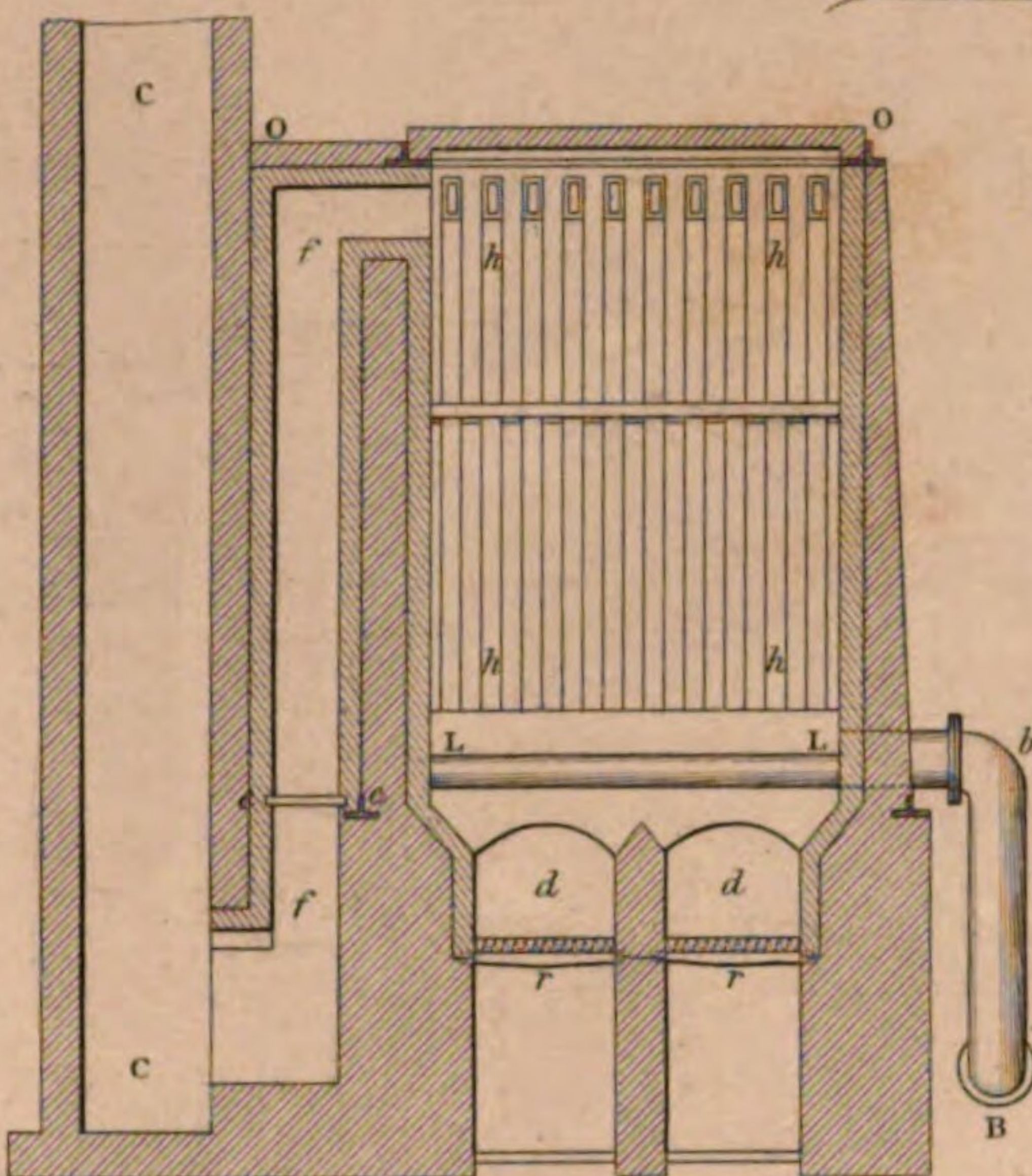
Detail of heating pipes.



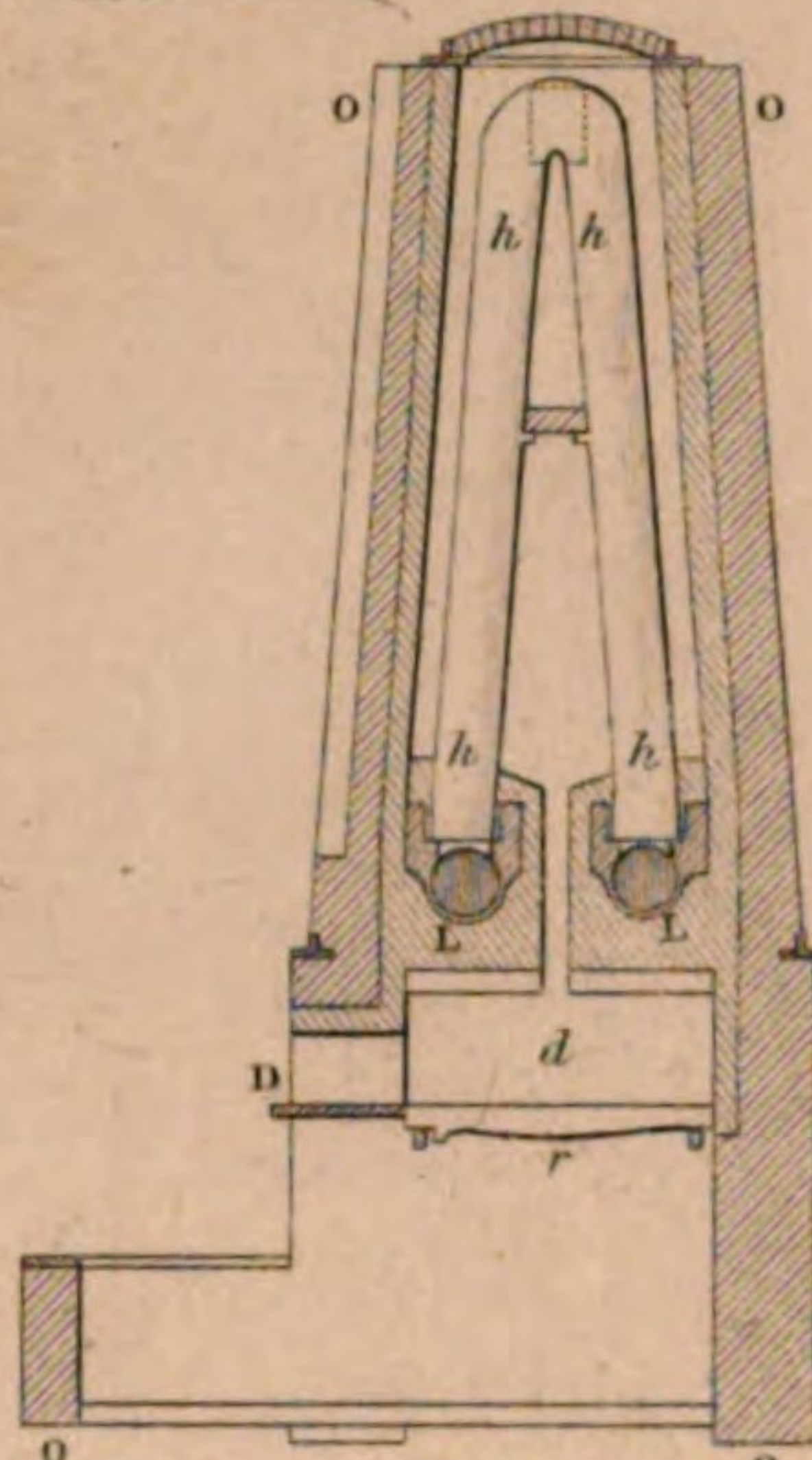
Transverse Section.



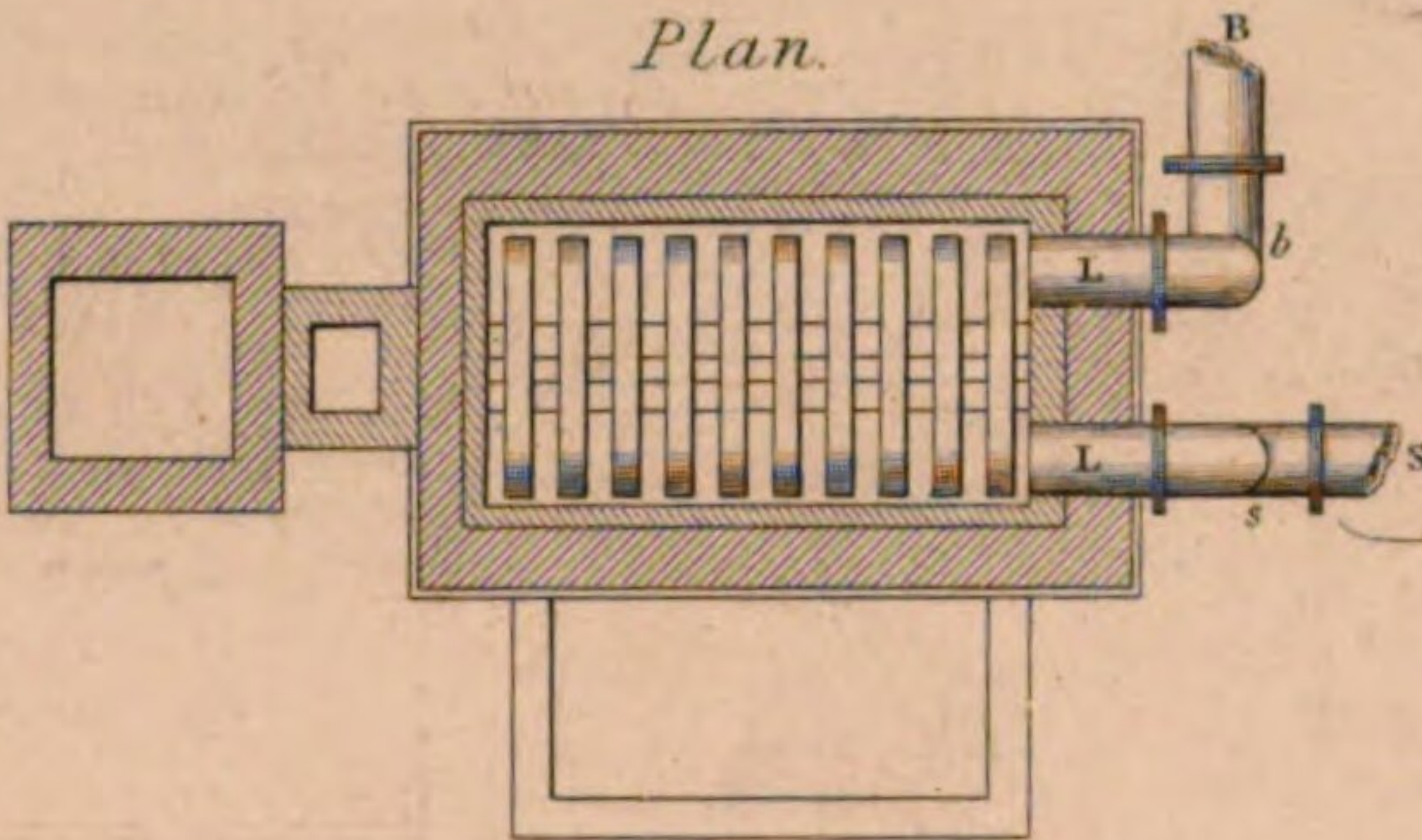
Long. Section.



Transverse Section.



Plan.



Detail of heating pipes.

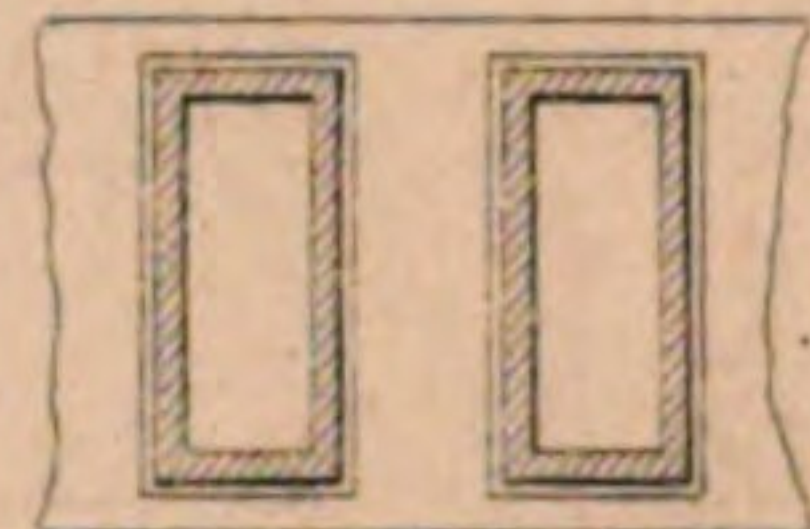
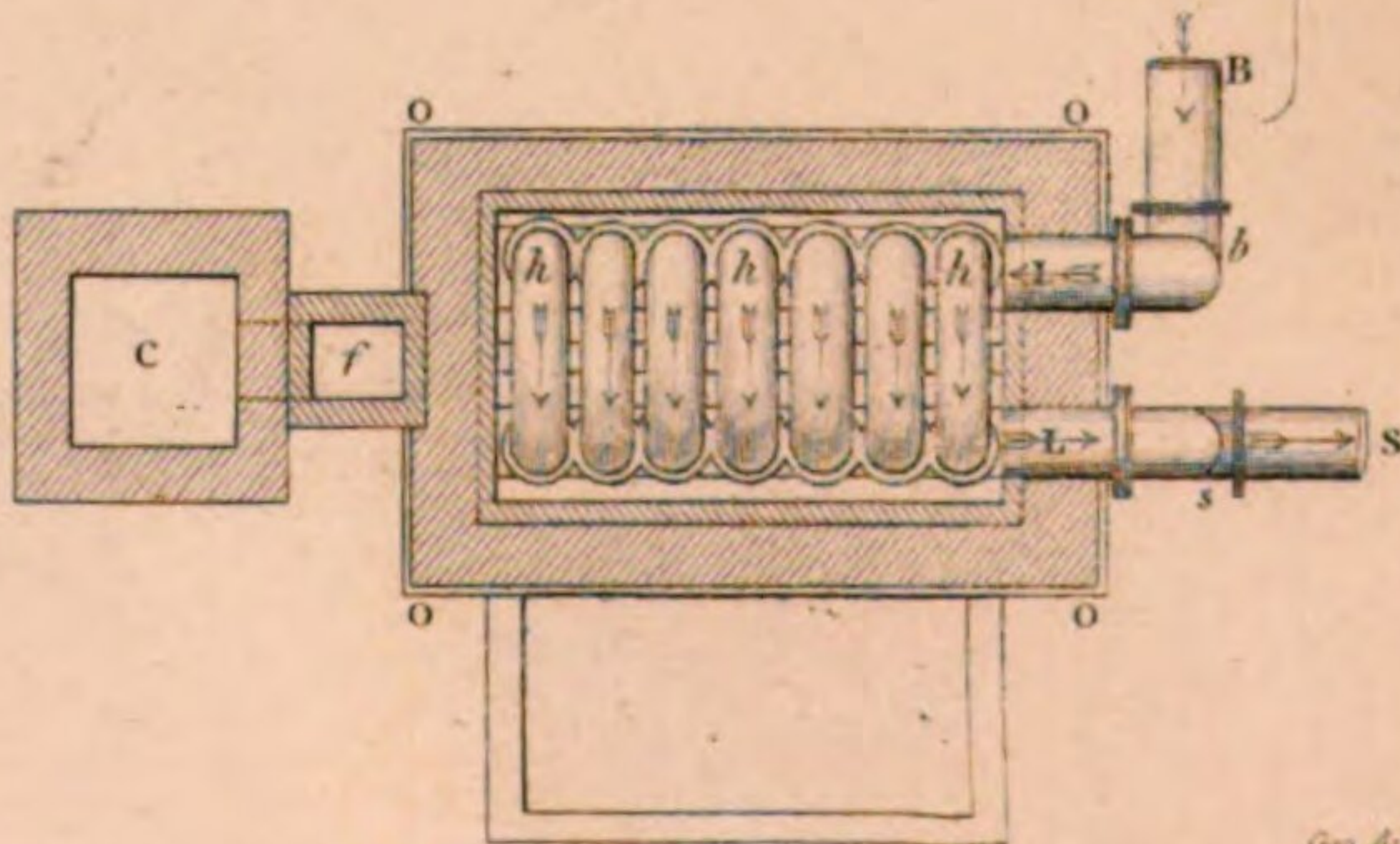
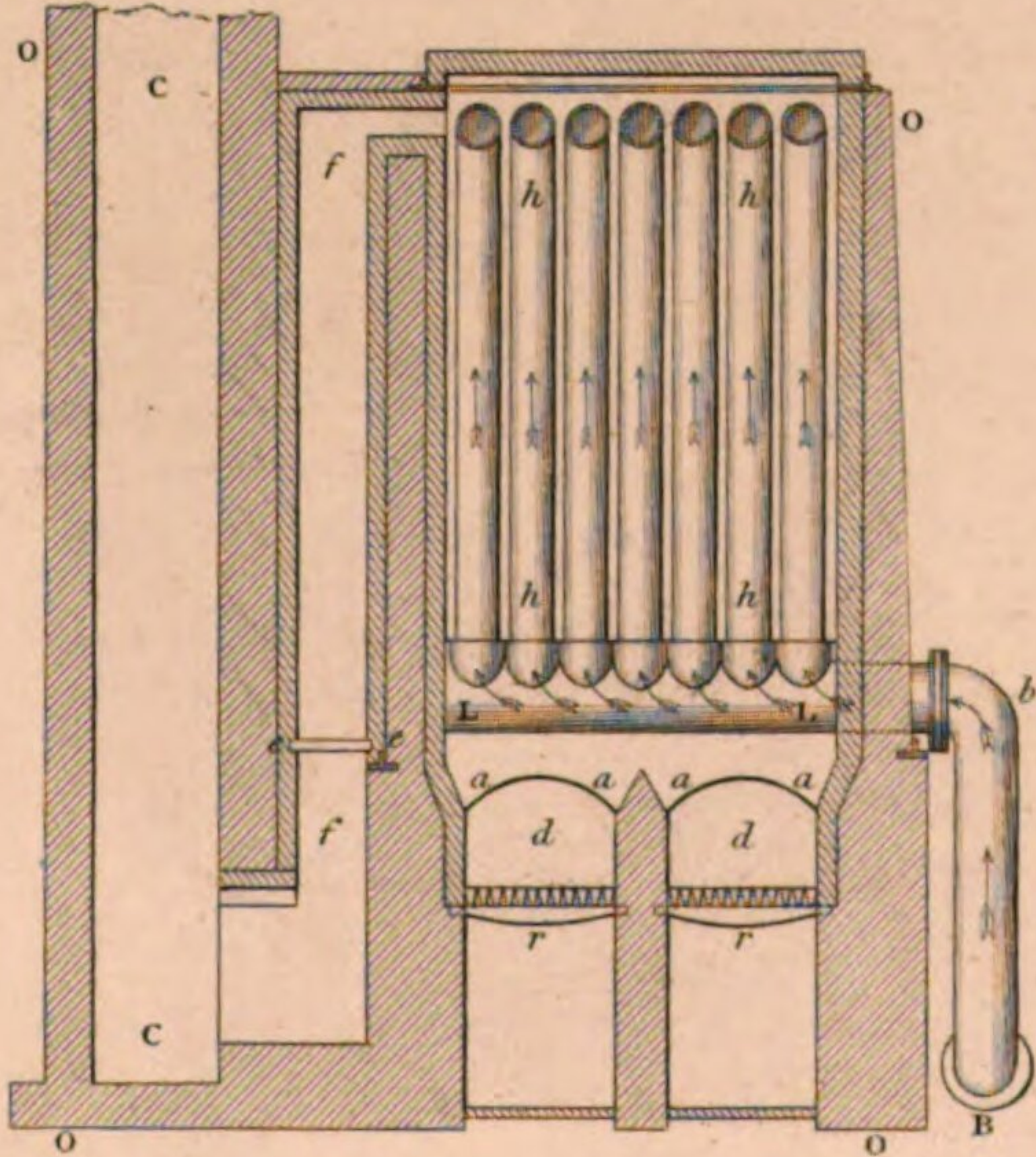
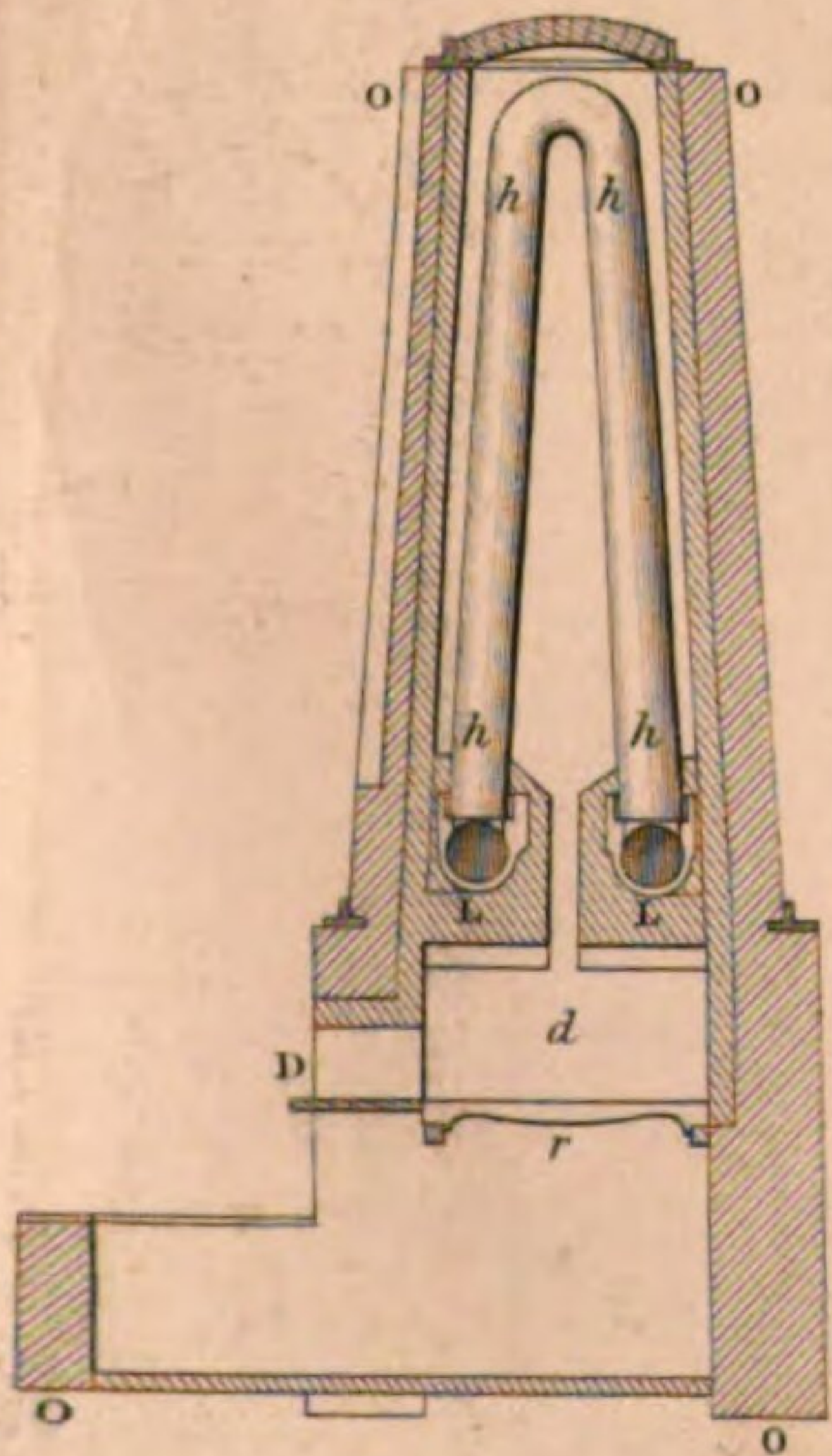
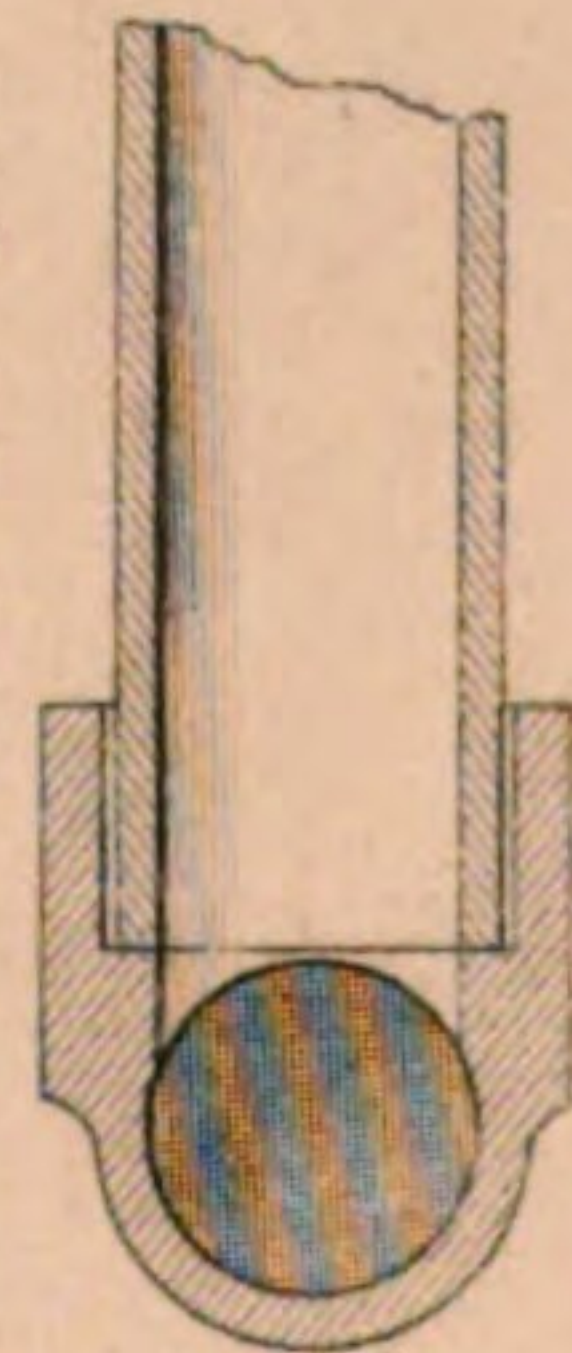


Fig. 5.

Joint of Heating pipe in lying pipe.



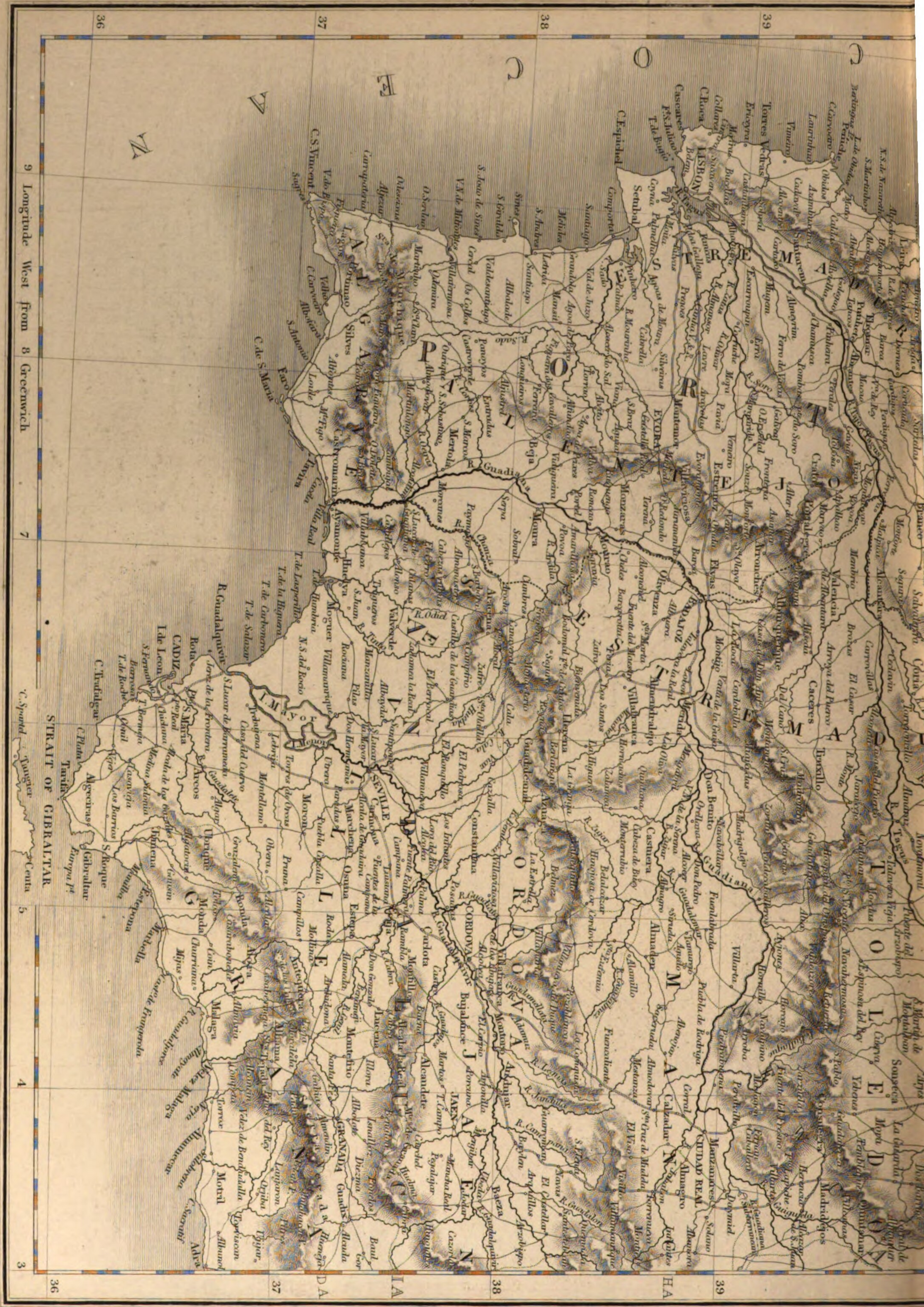


SPAIN & PORTUGAL

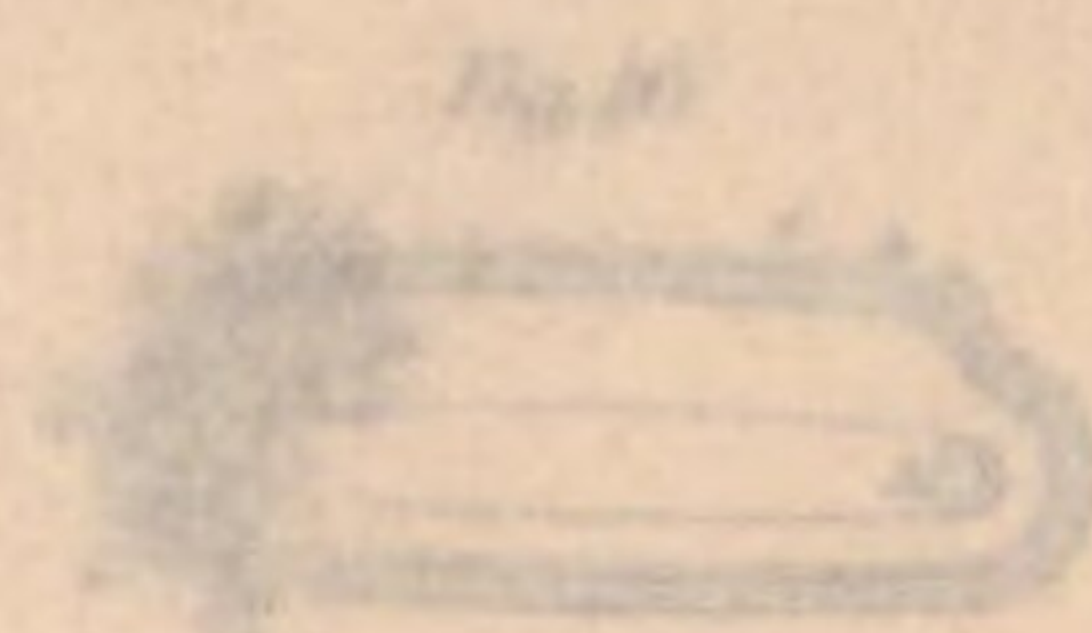
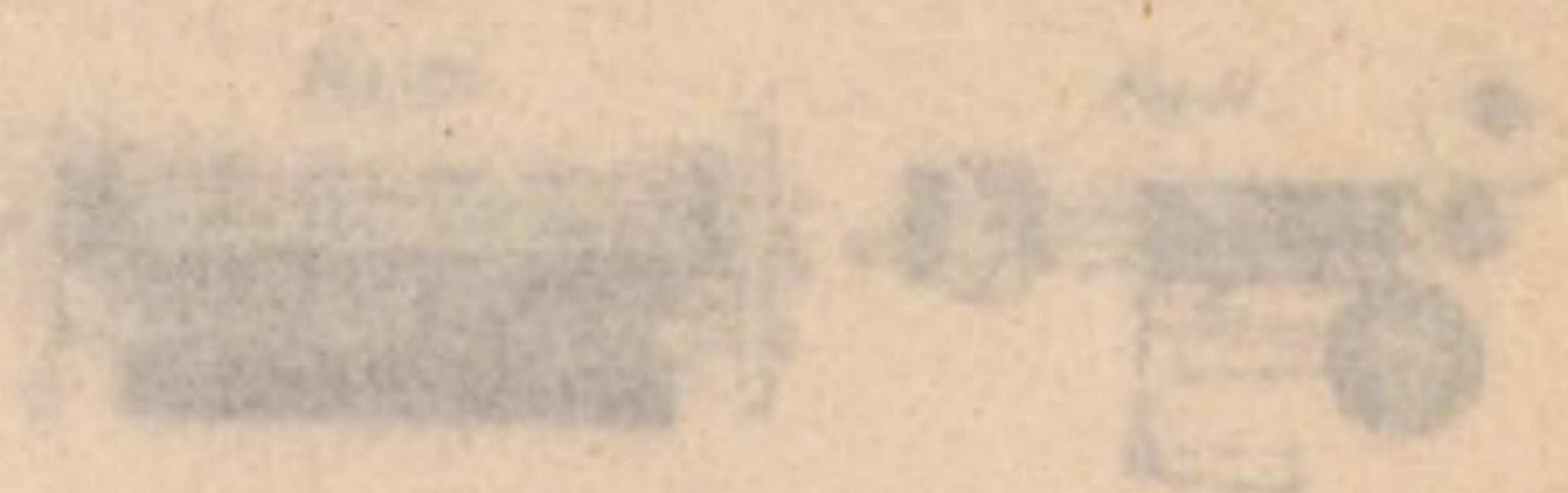
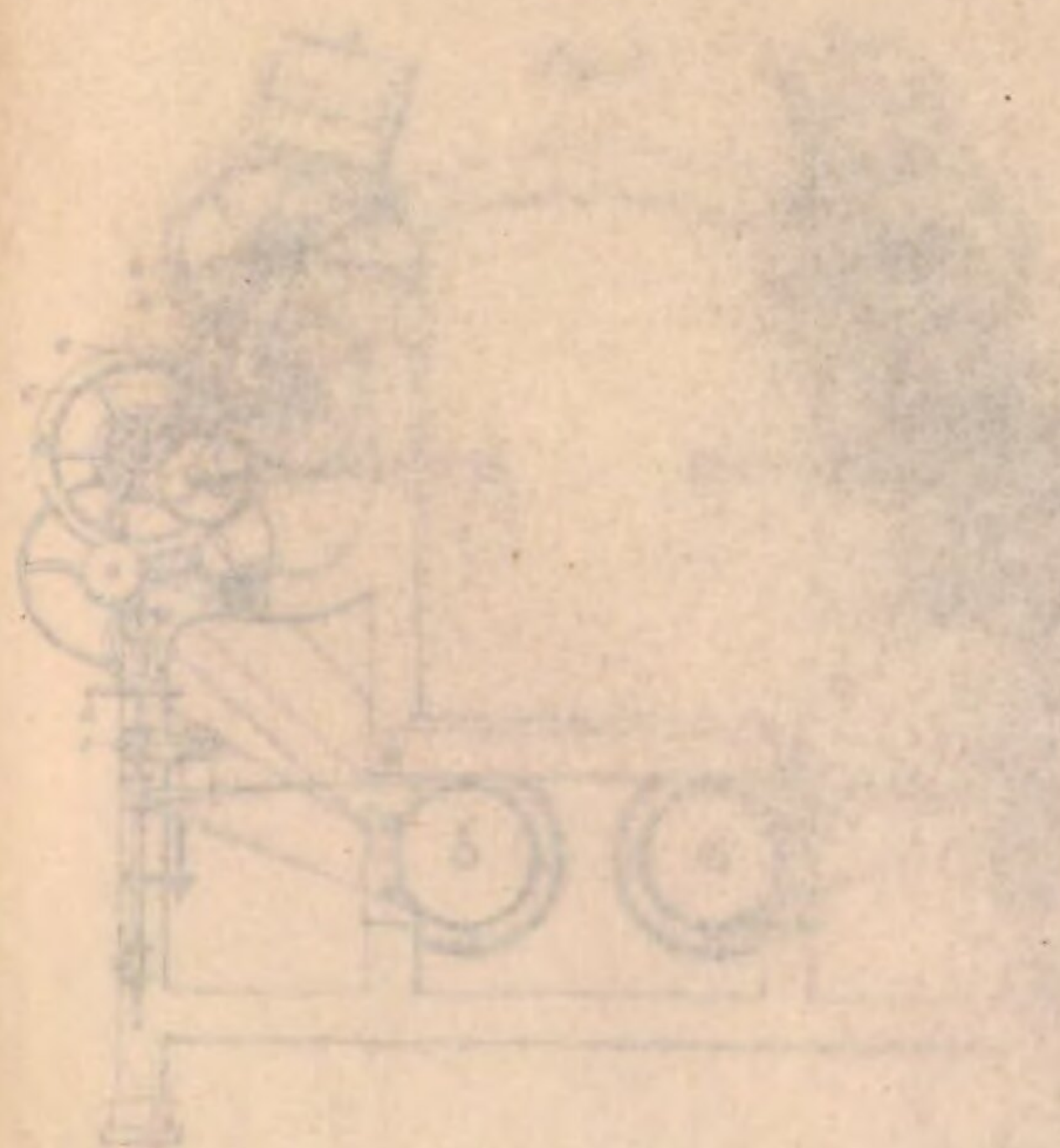
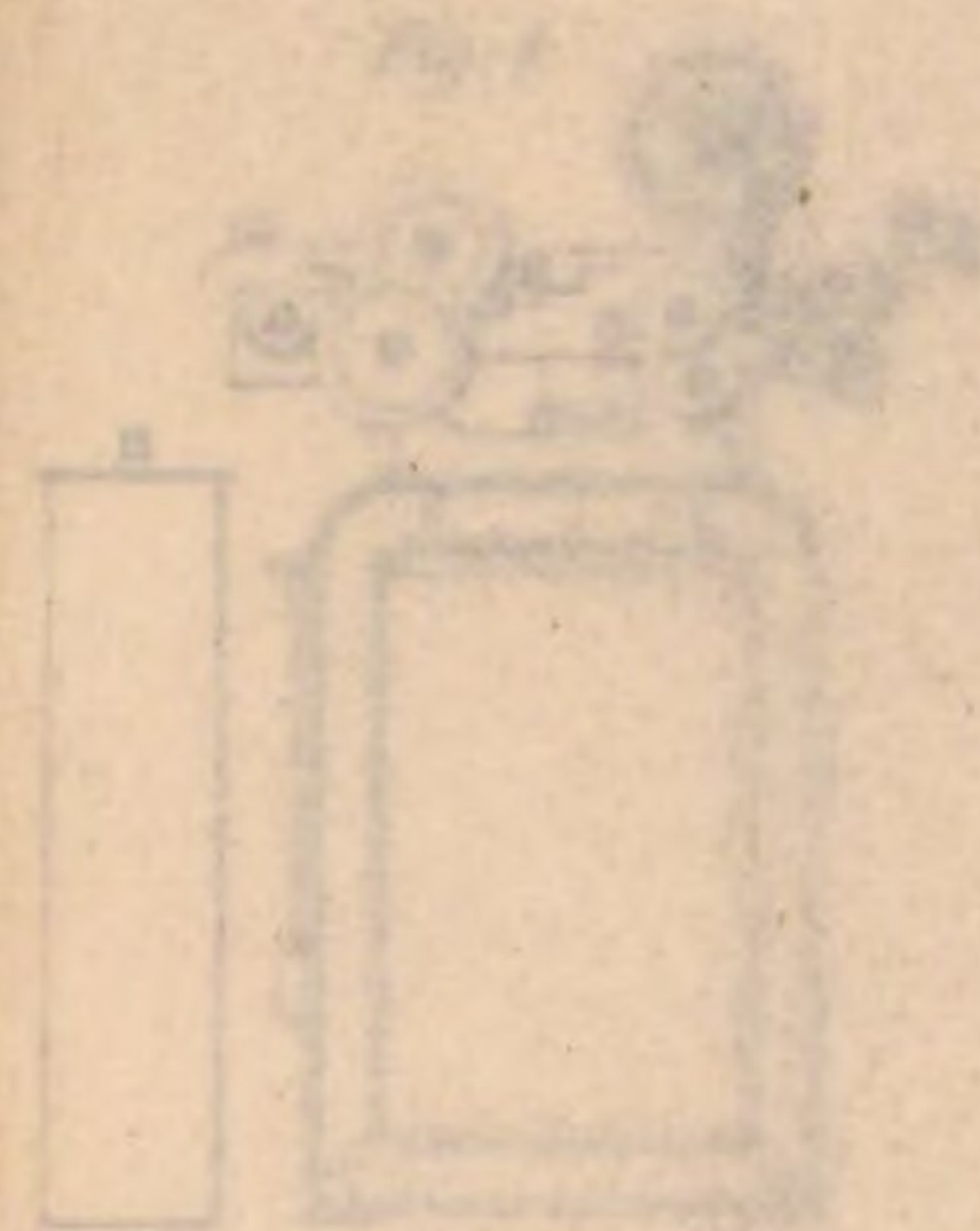
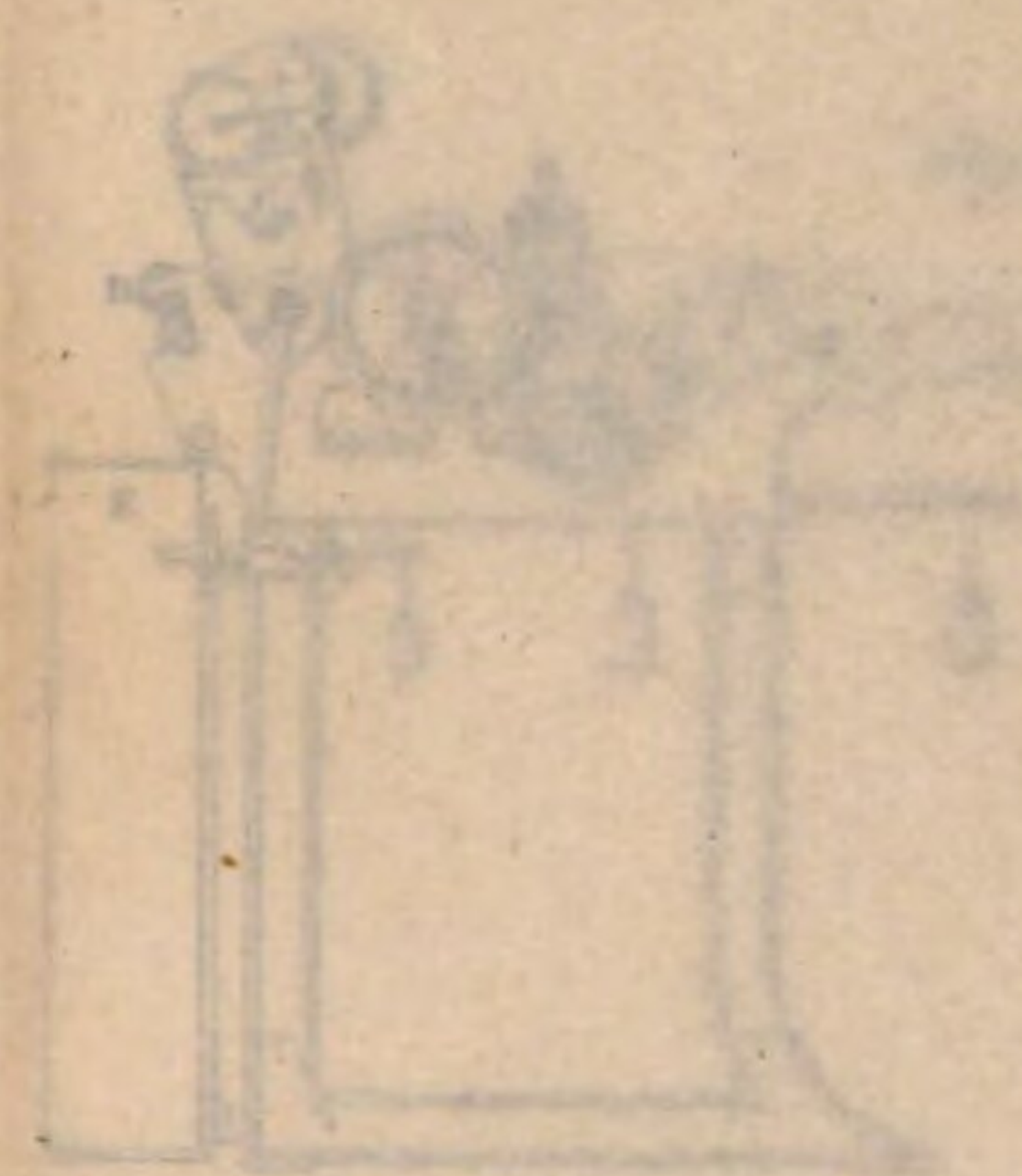
English Miles
0 5 10 20 30 40 50 60 70

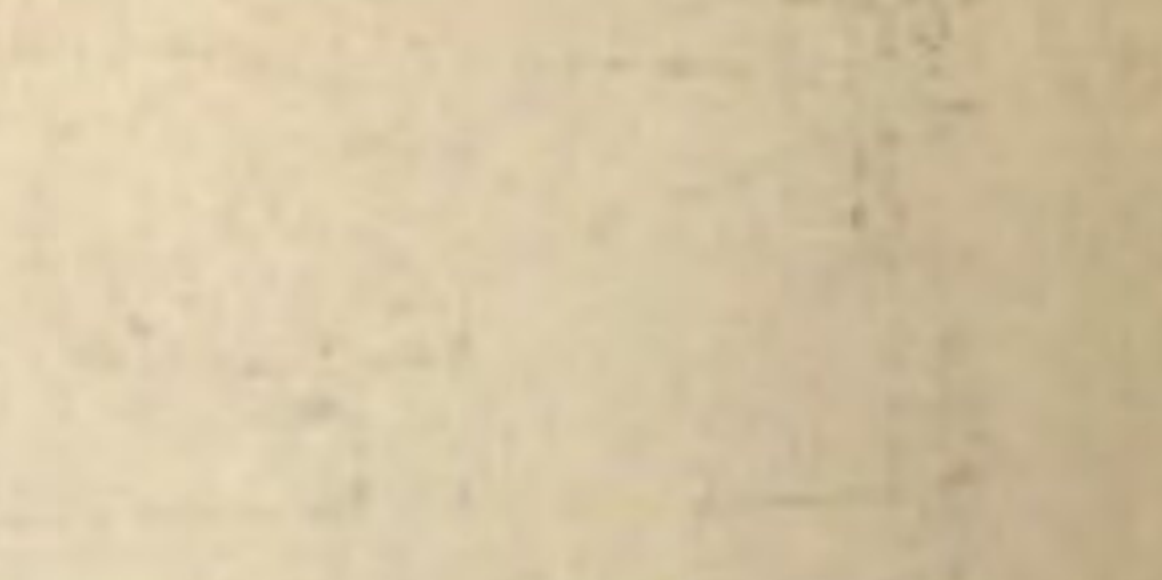
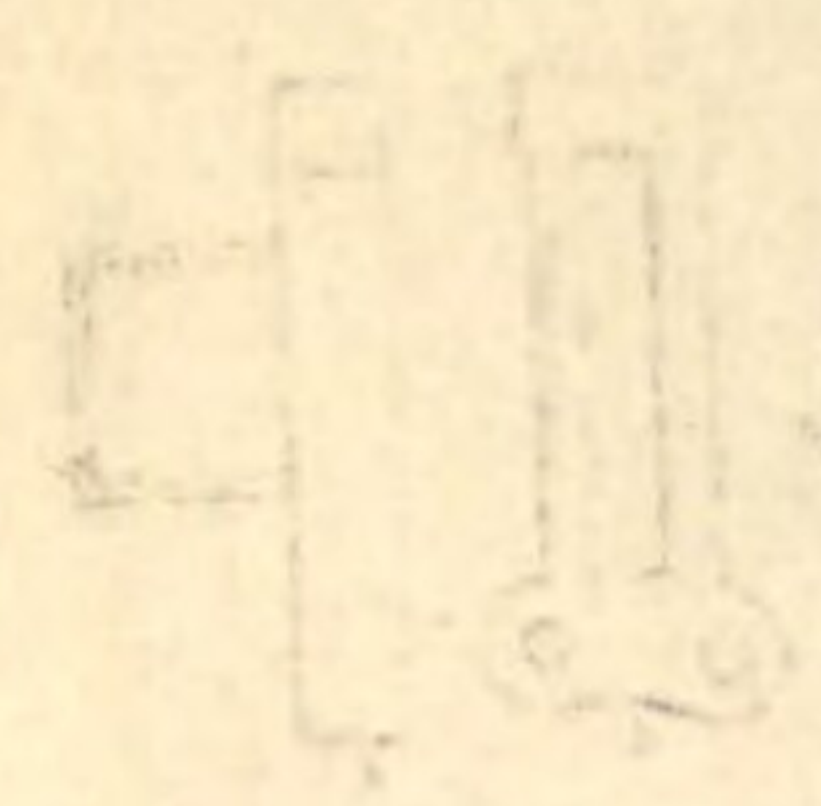
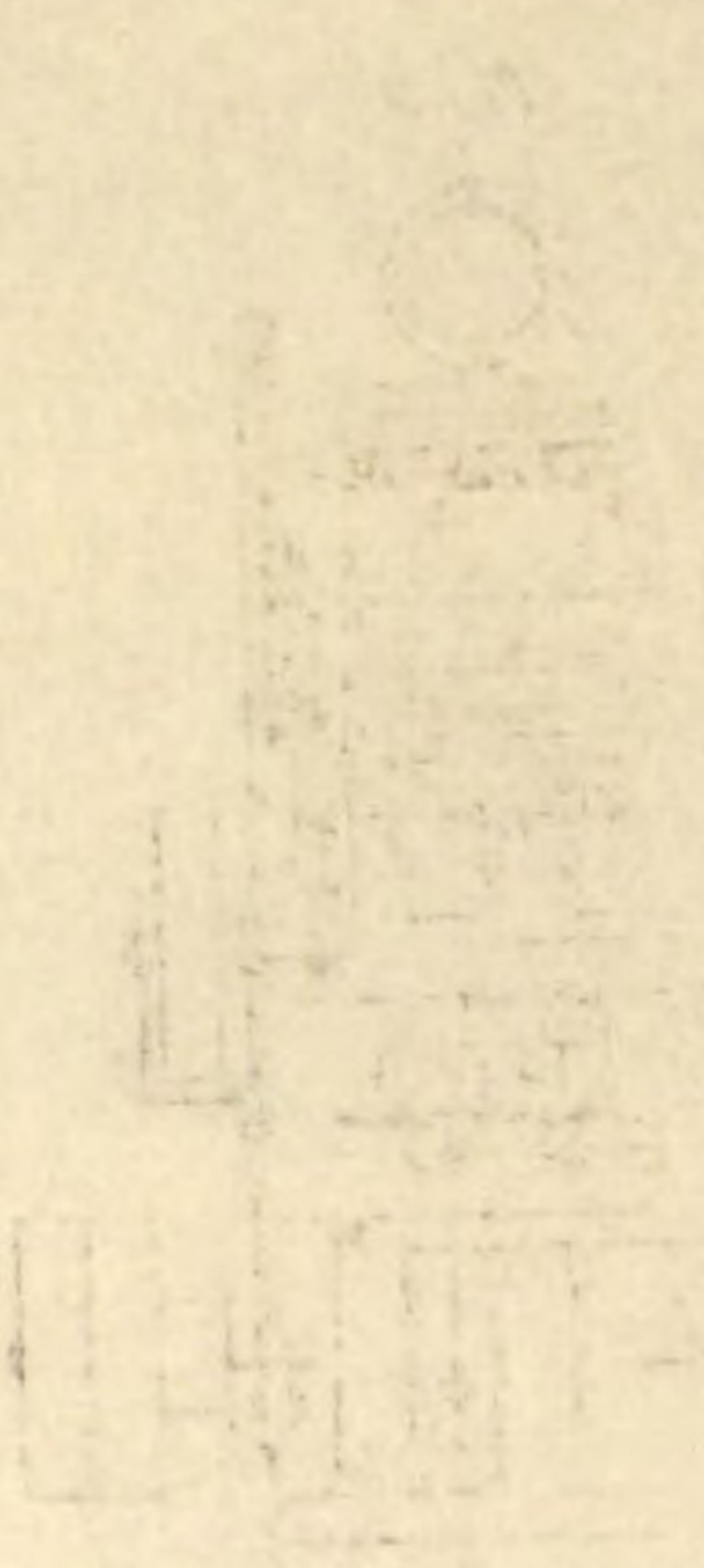
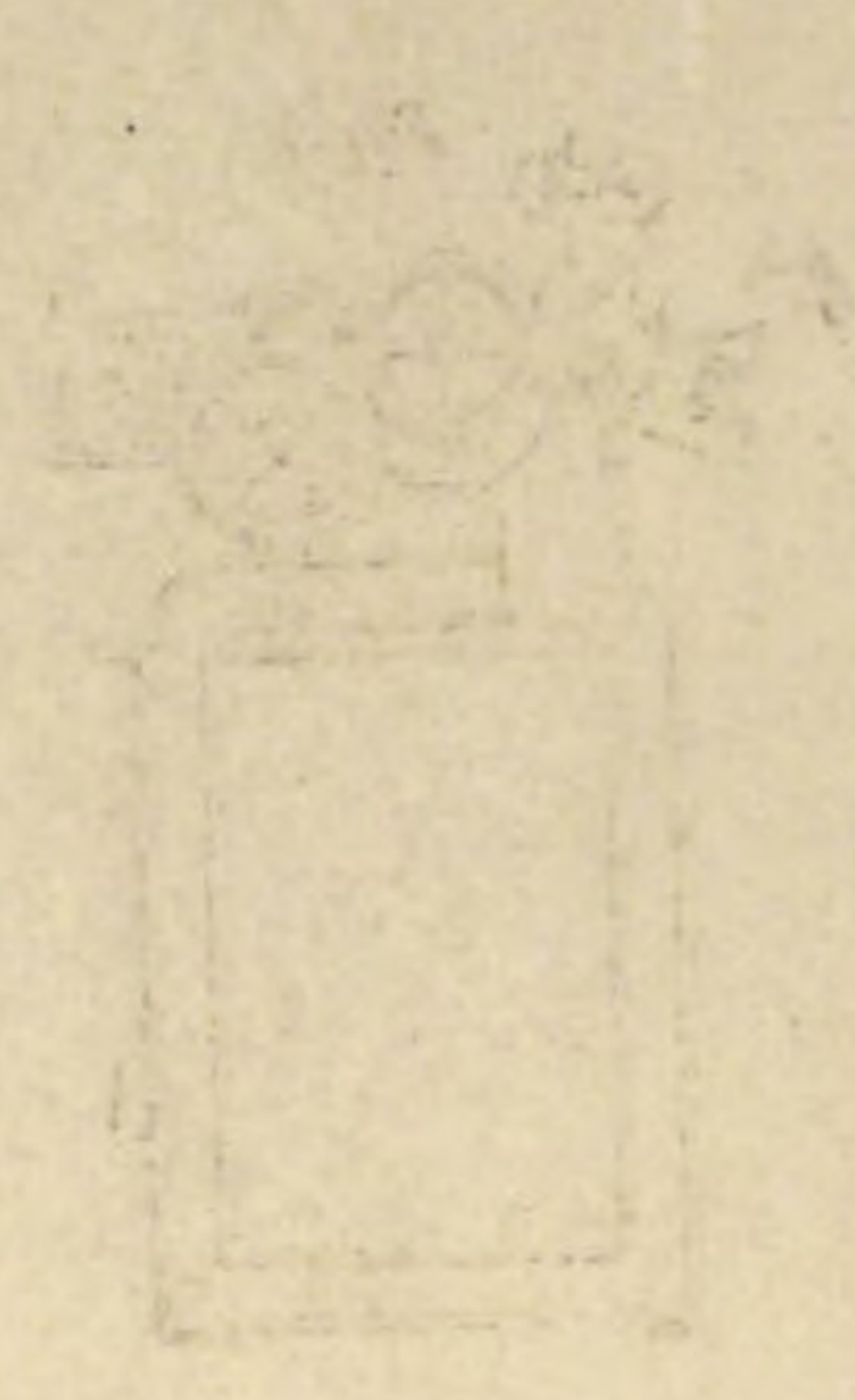
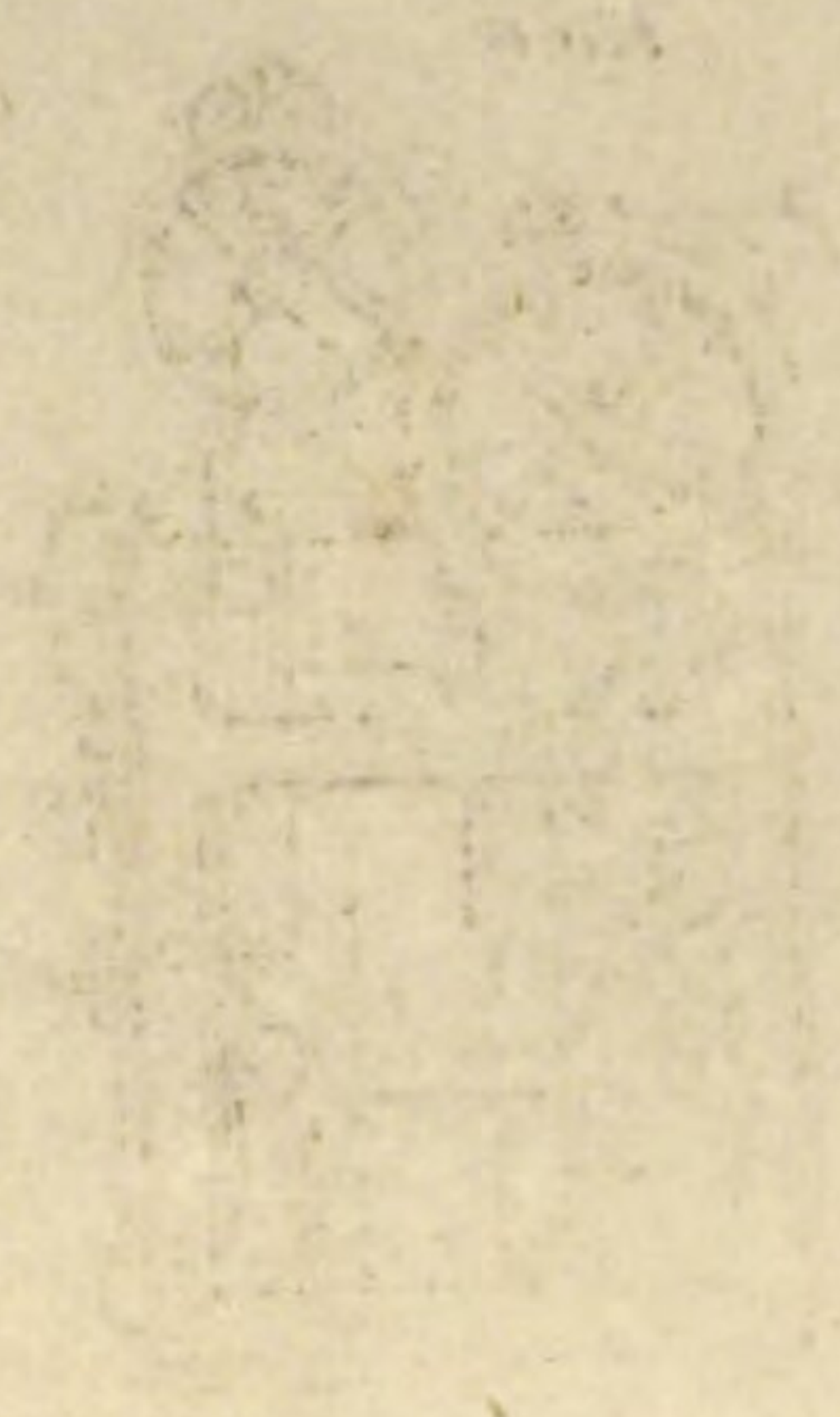
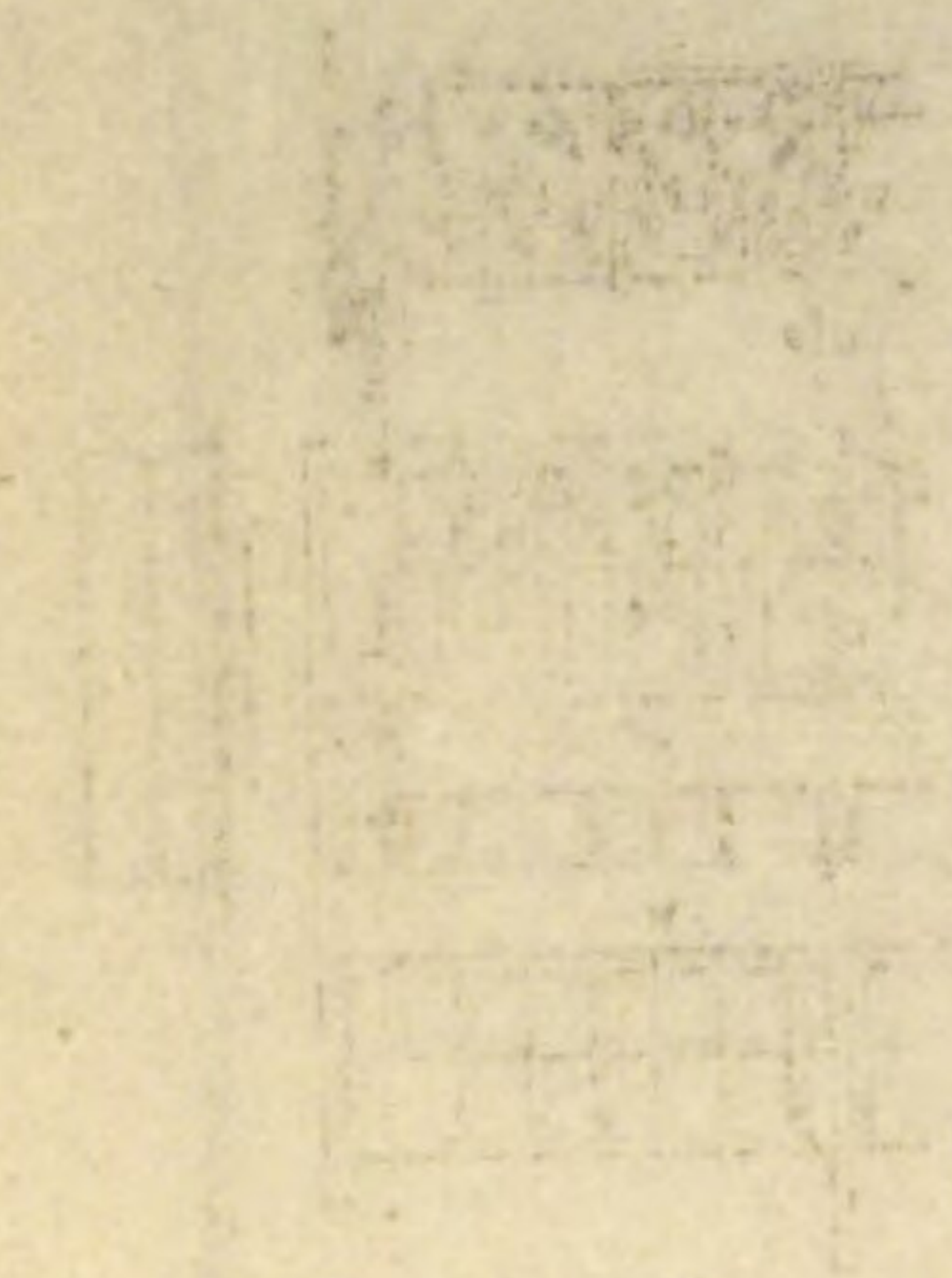
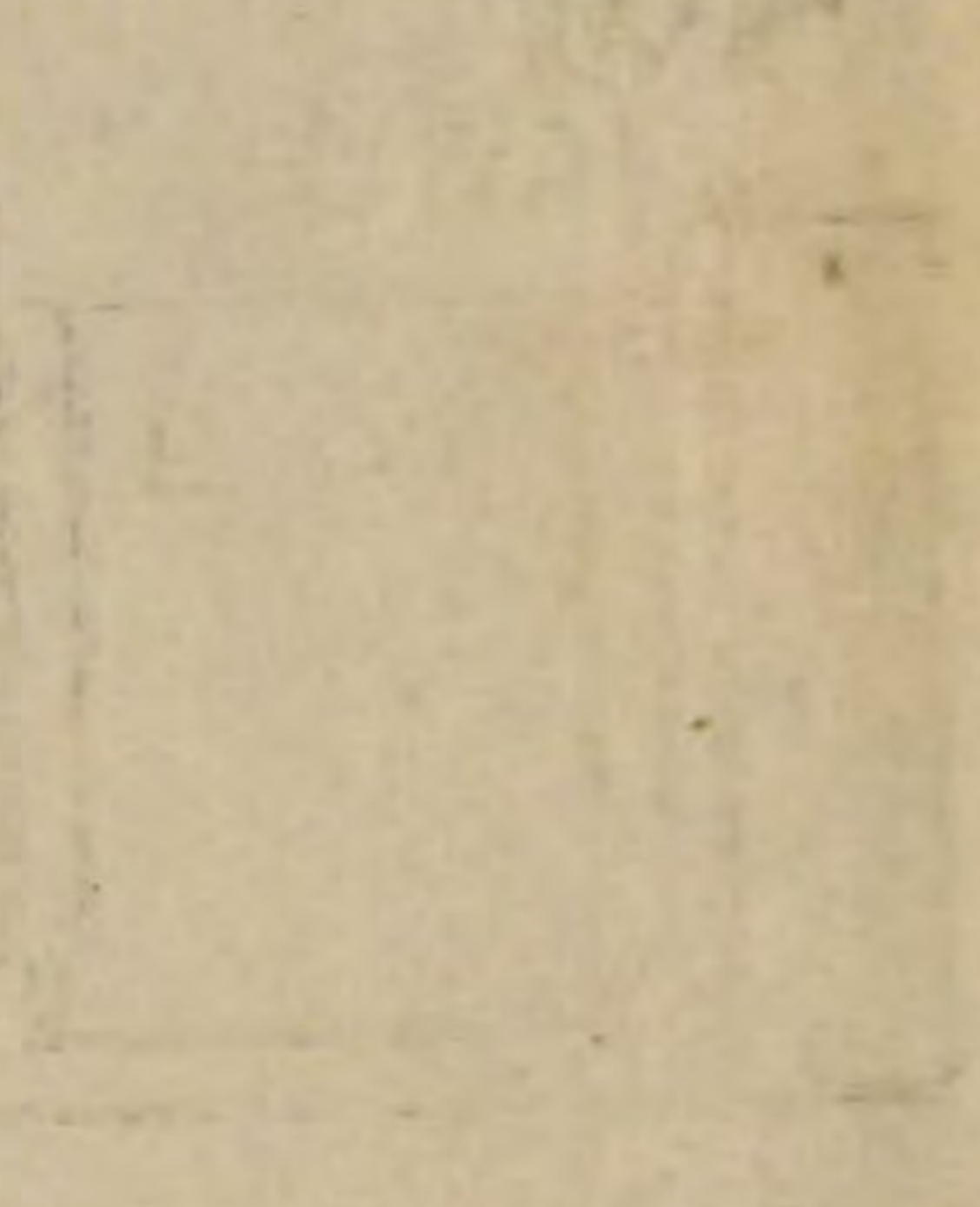
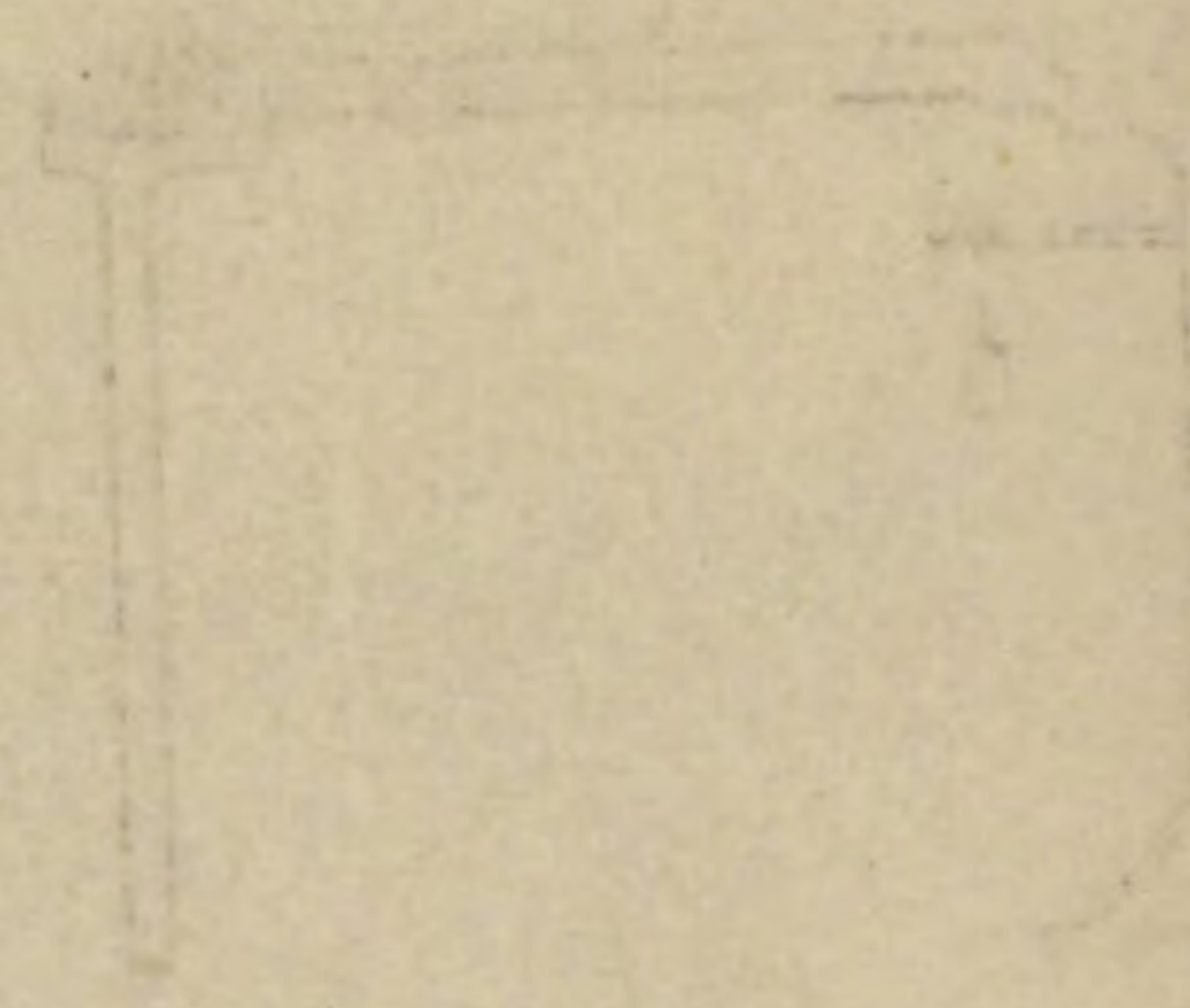
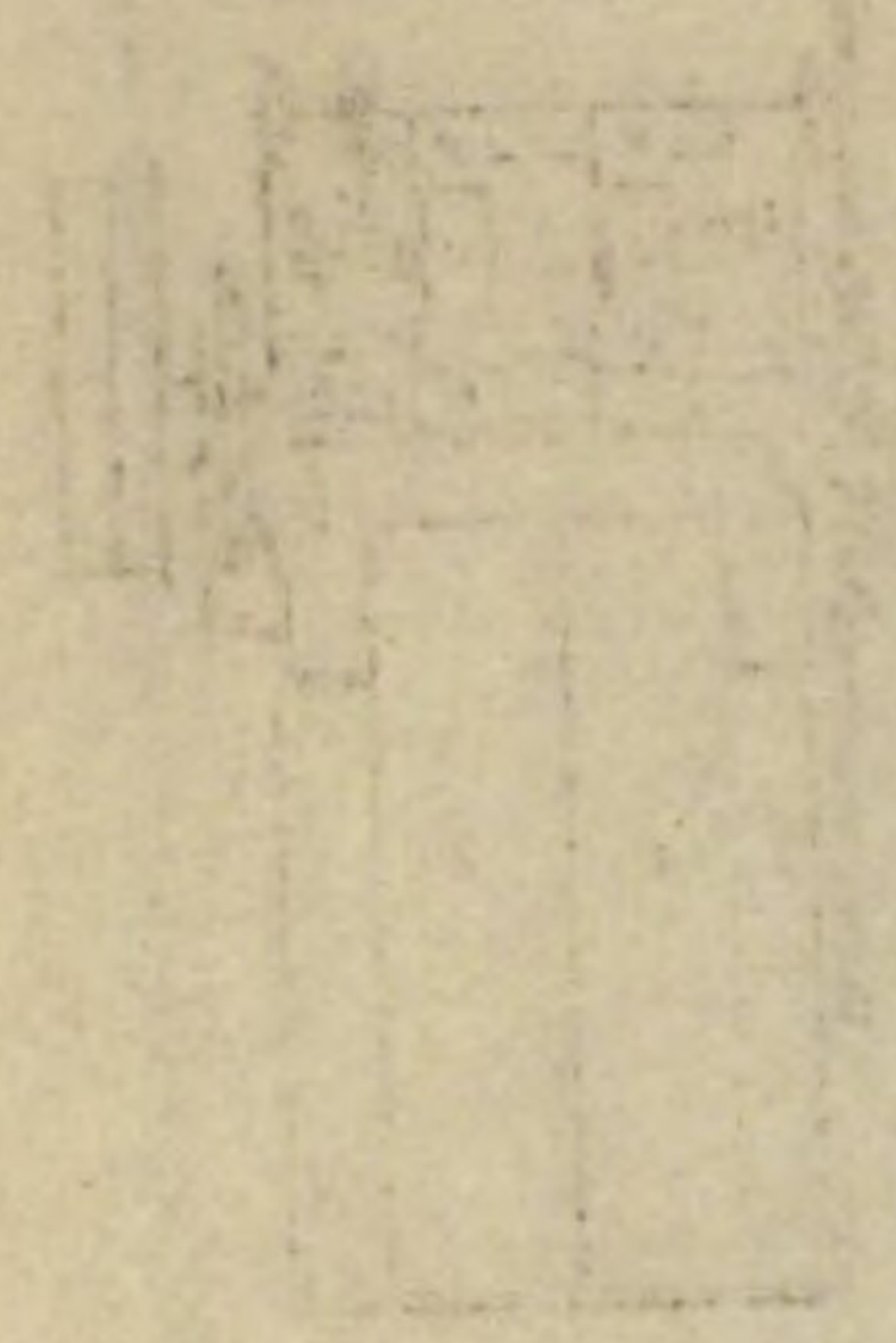
In Spanish names X and I are used indifferently; both letters being pronounced exactly alike, with a sound, the nearest approach to which that can be made in English is that of a strongly aspirated H.











SPINNING.

PLATE CCCCLXV.

Fig. 1.

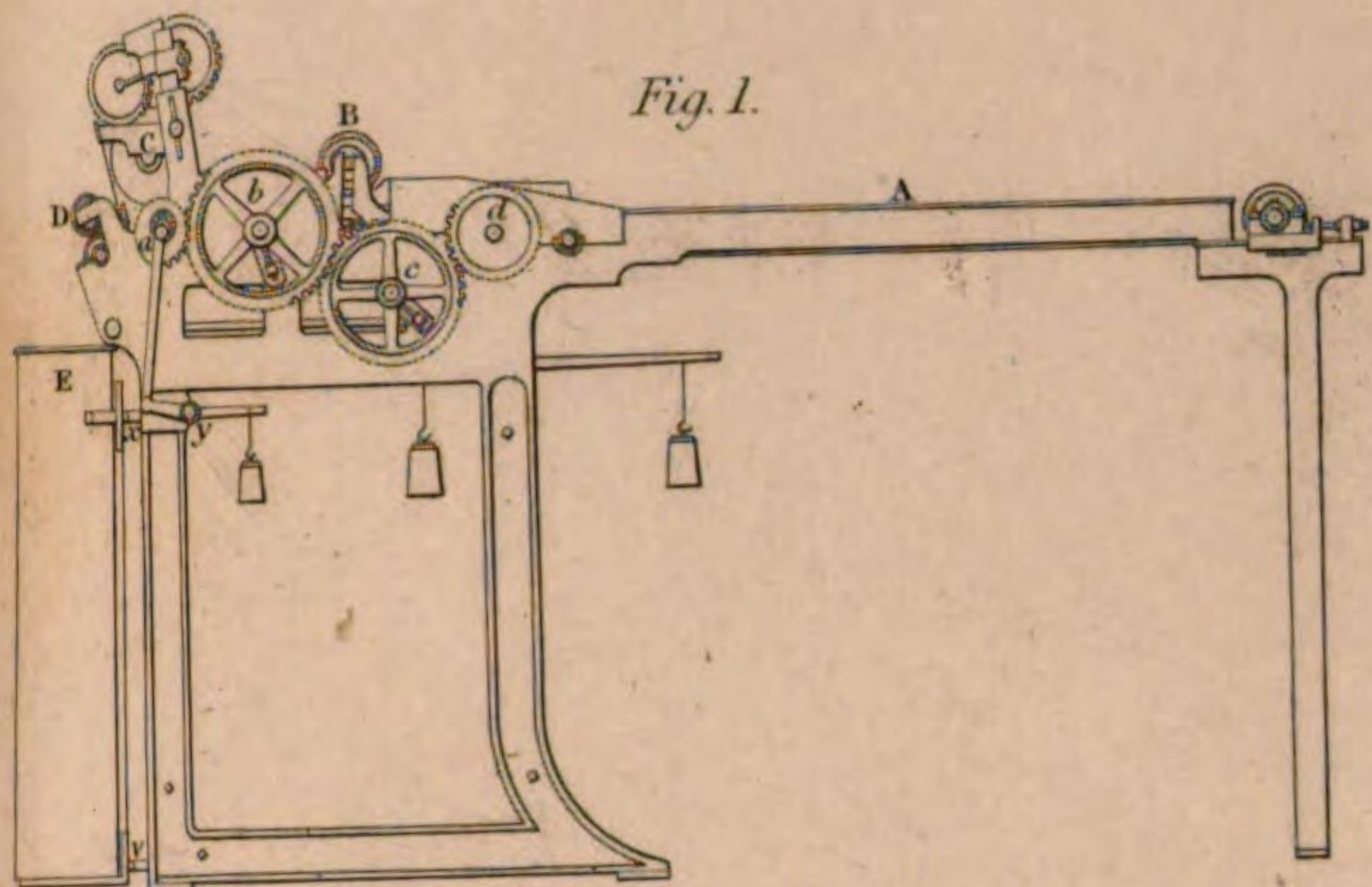


Fig. 3.

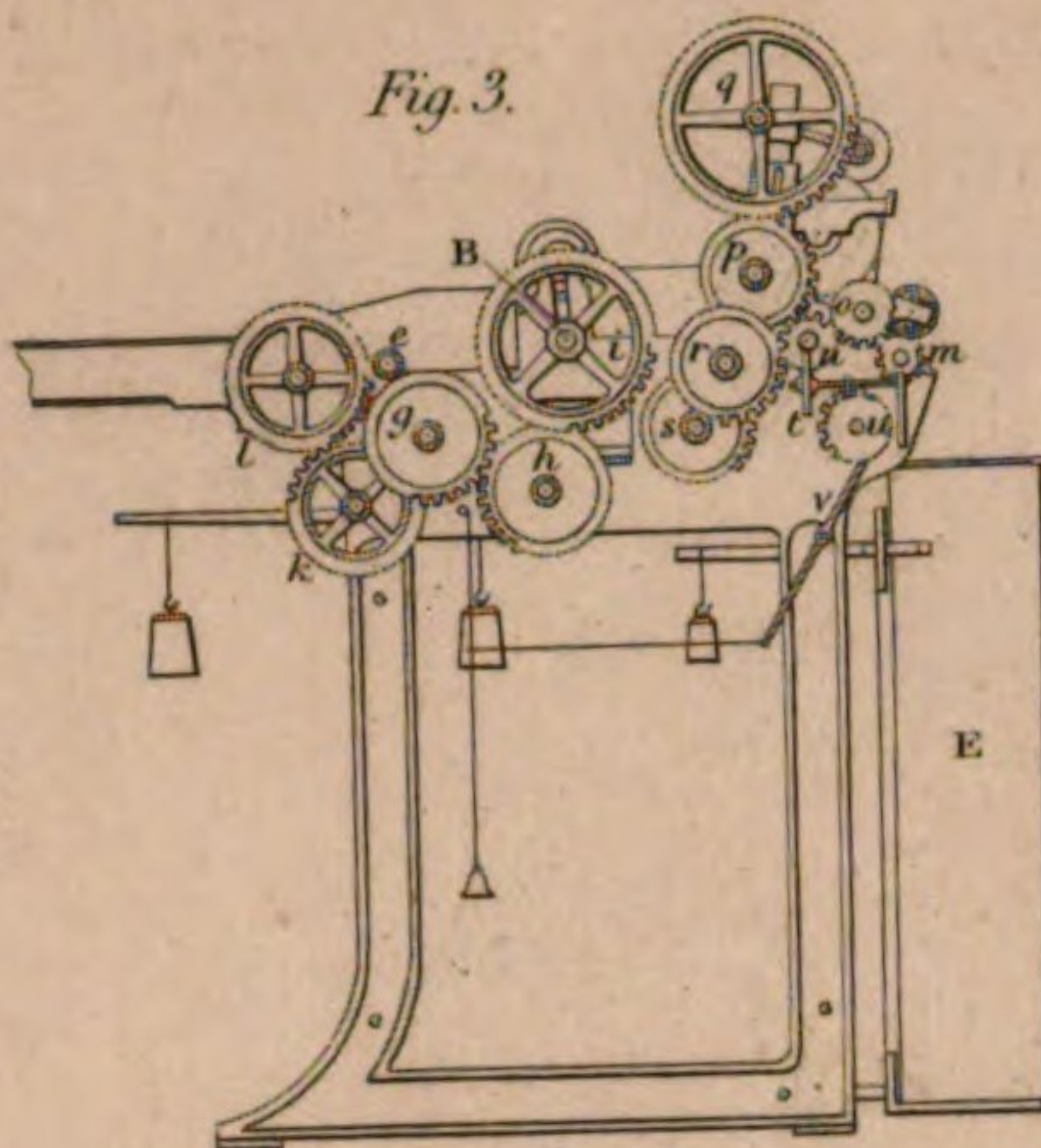


Fig. 2.

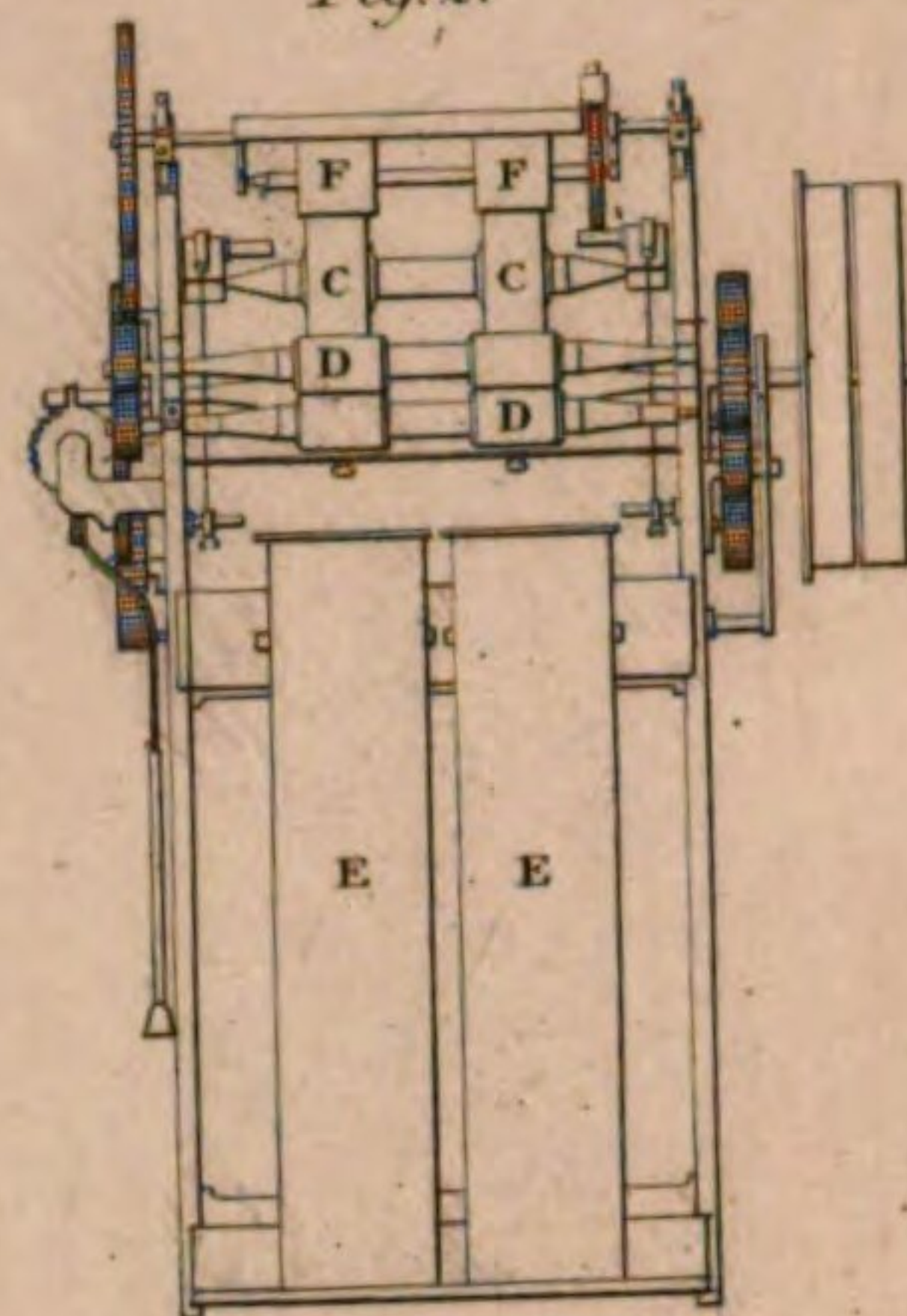


Fig. 4.

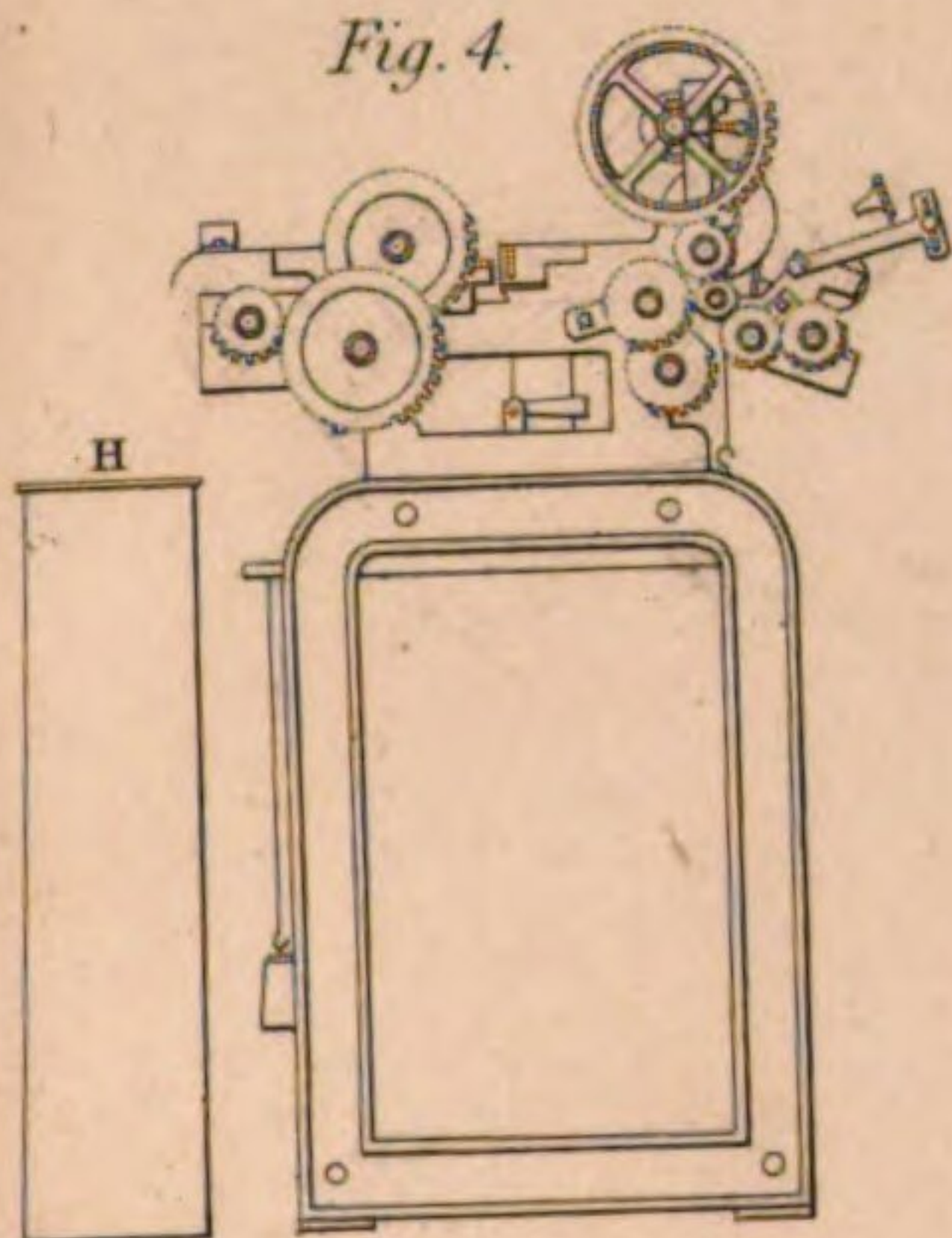


Fig. 5.

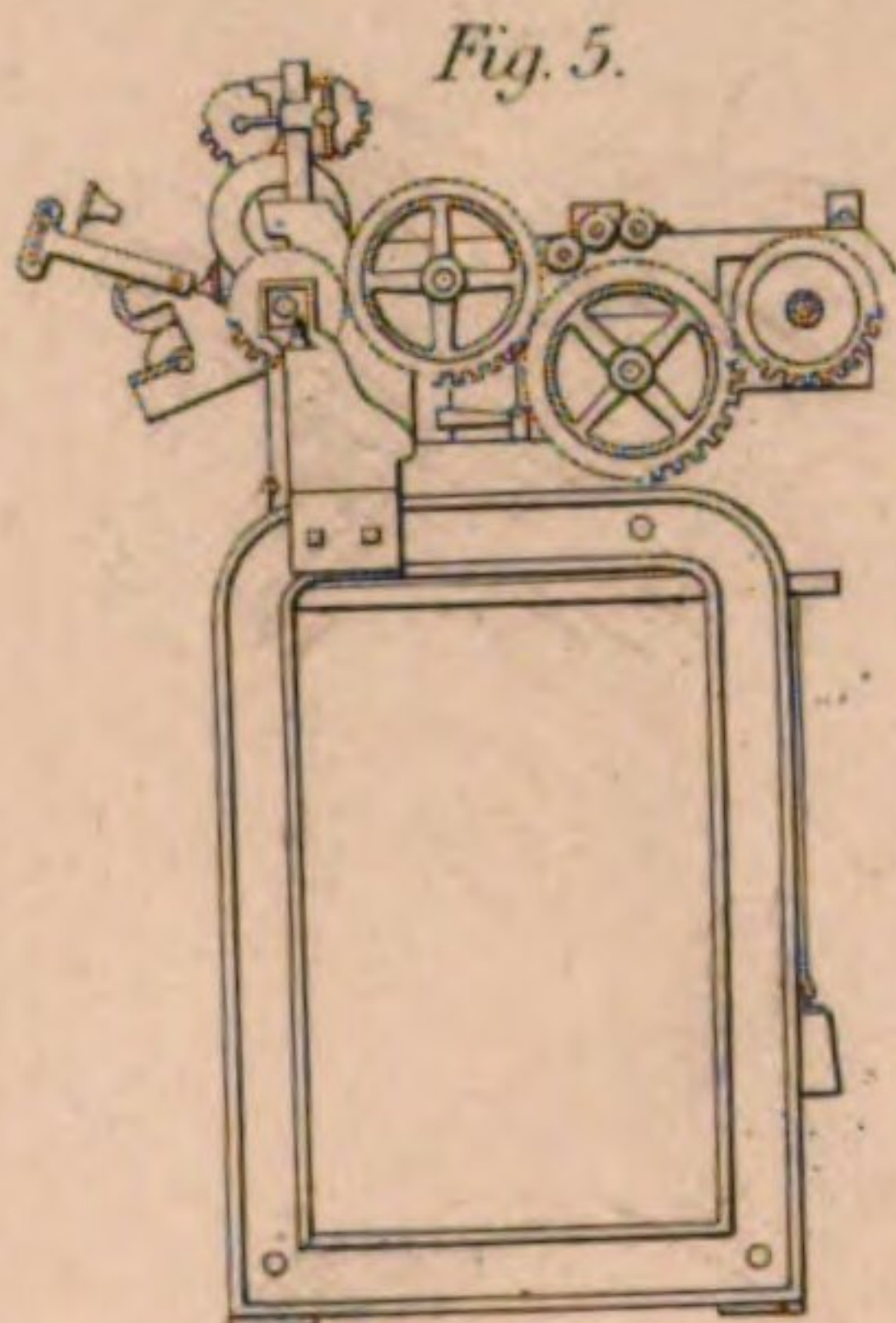


Fig. 6.

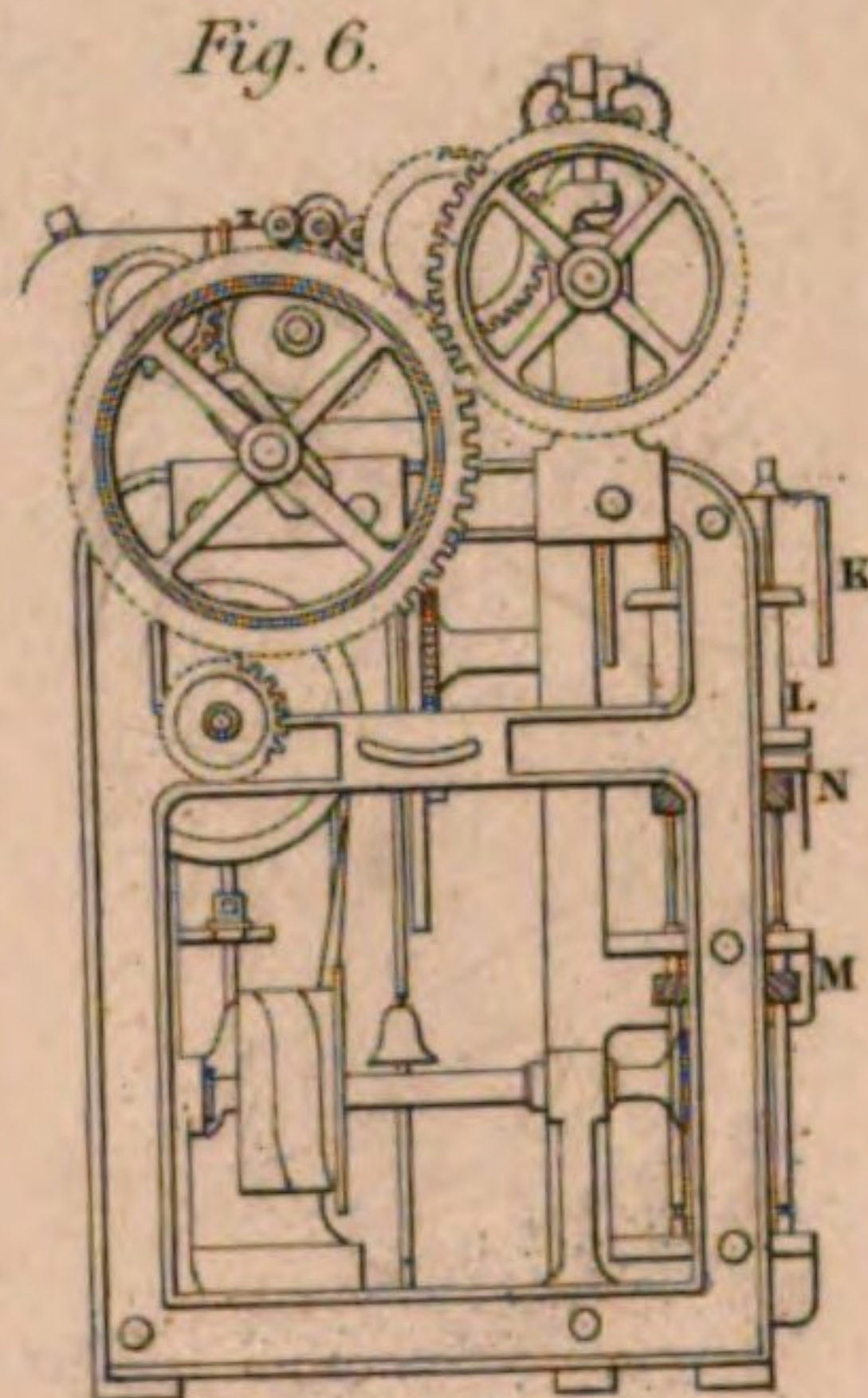


Fig. 7.

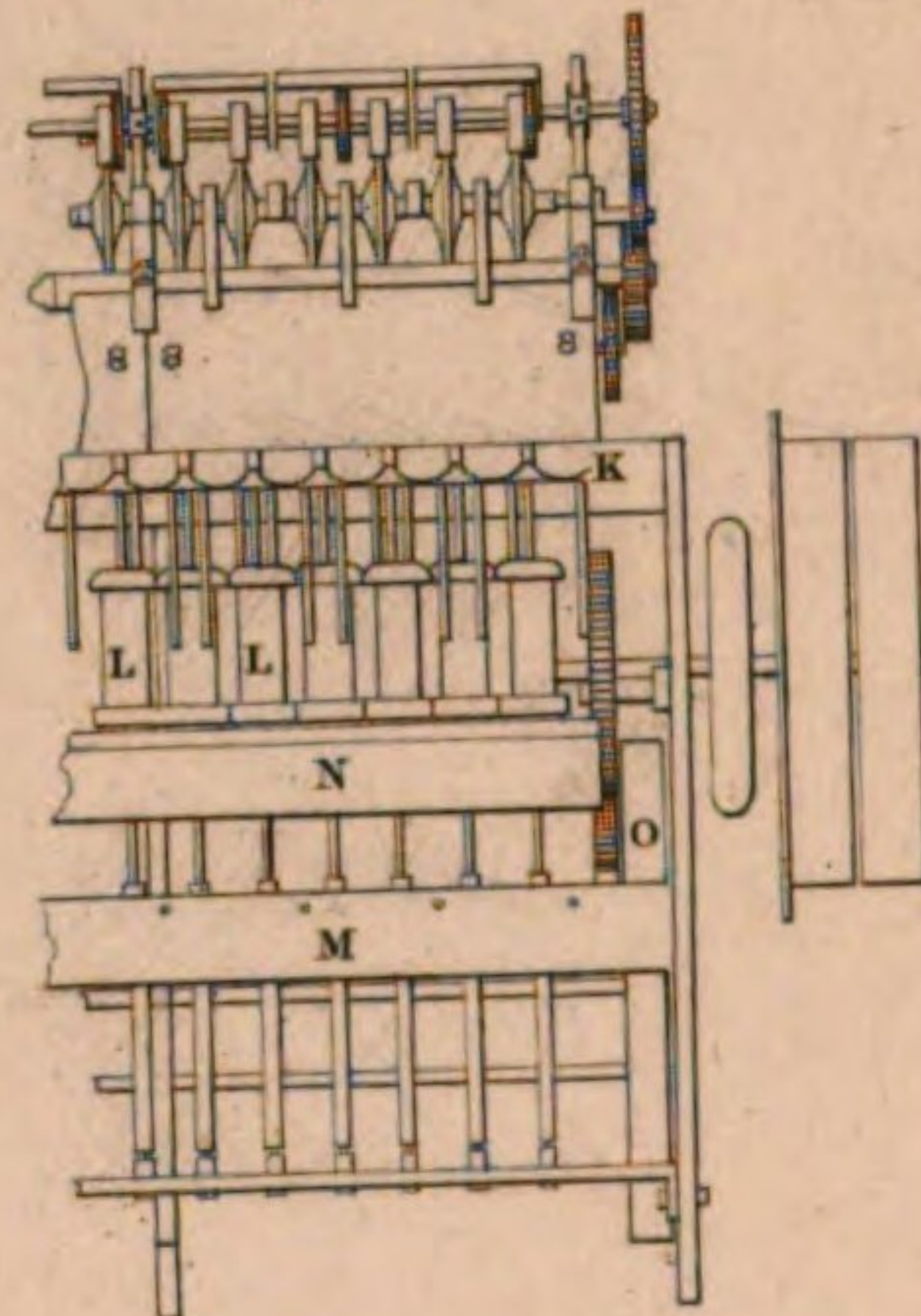


Fig. 8.

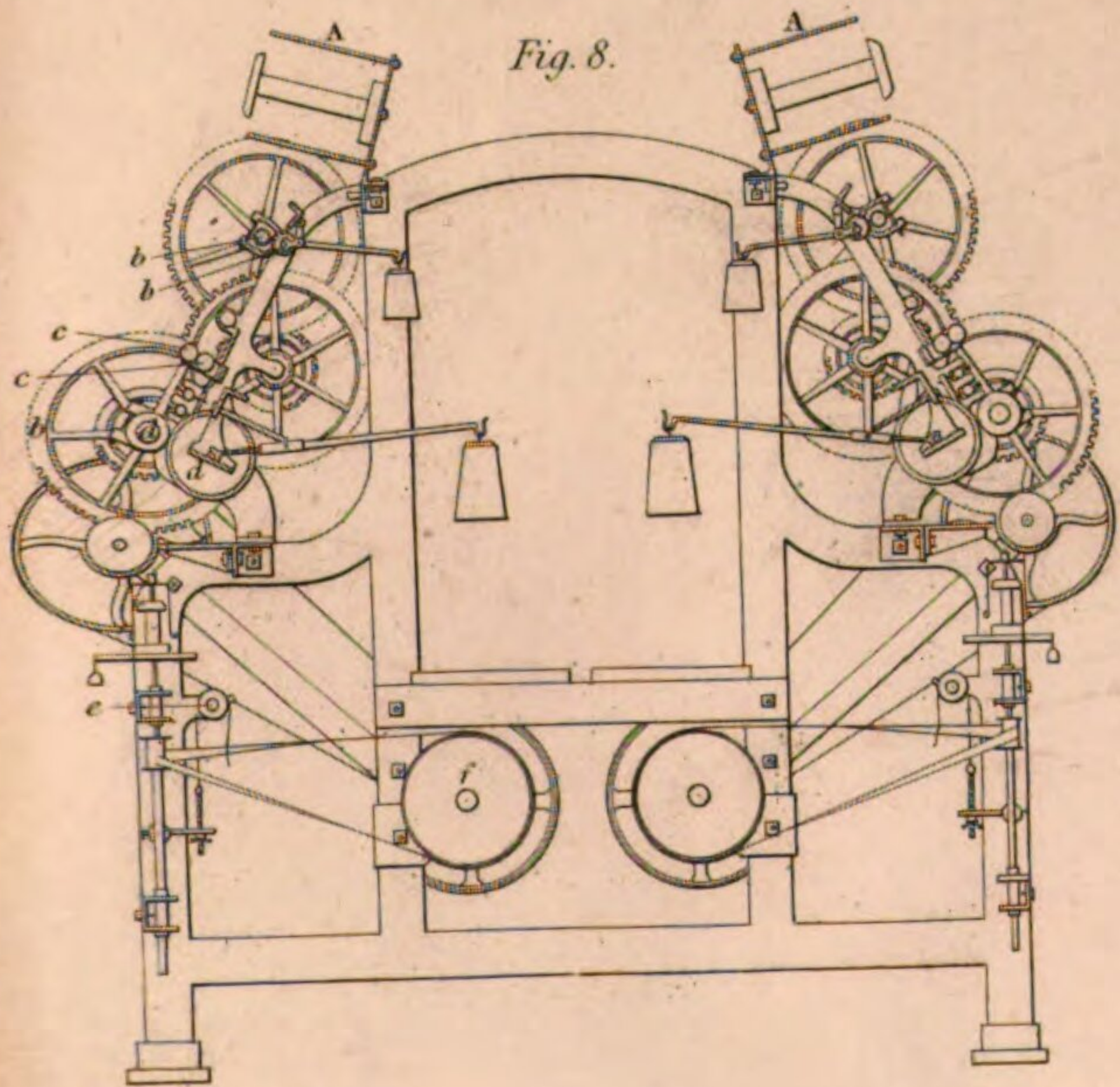


Fig. 9.

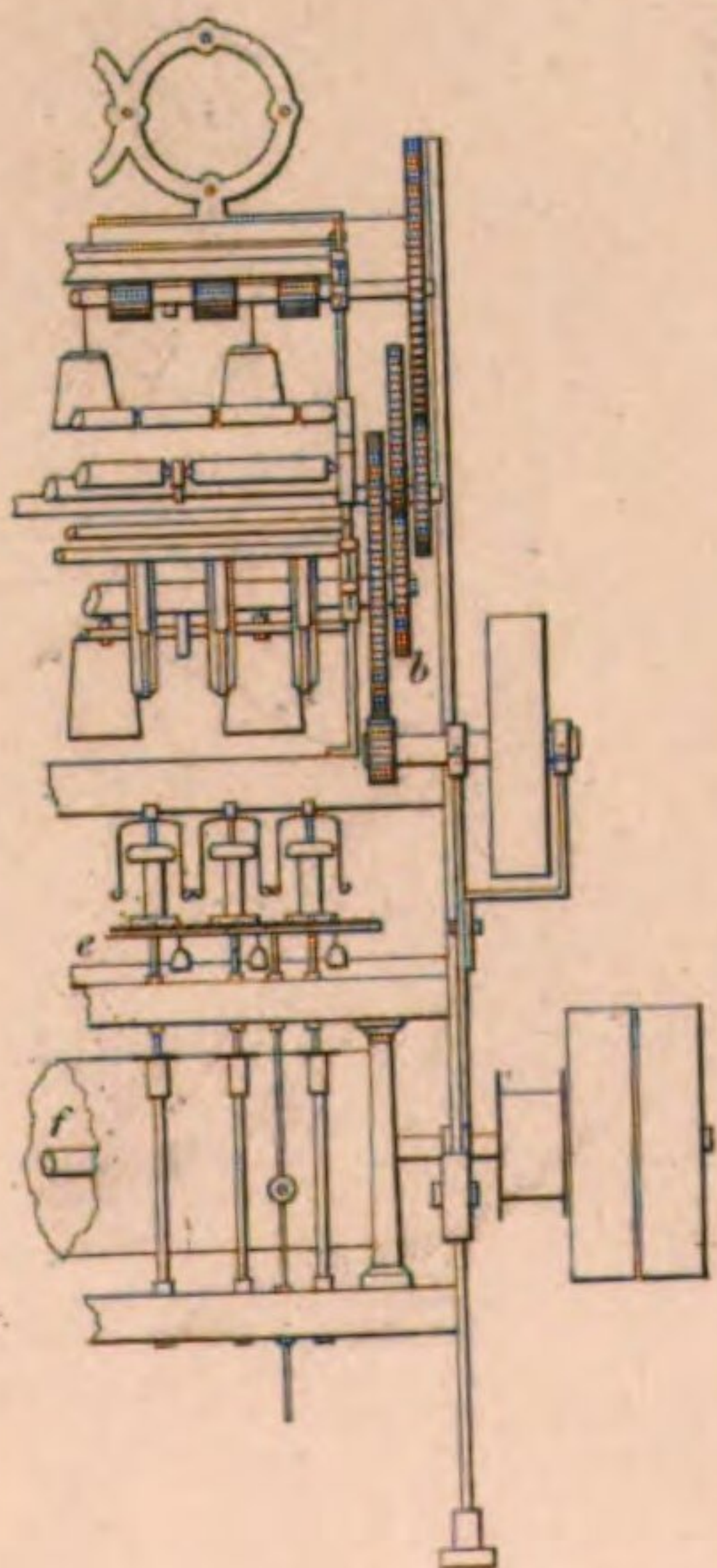


Fig. 12.



Fig. 11.

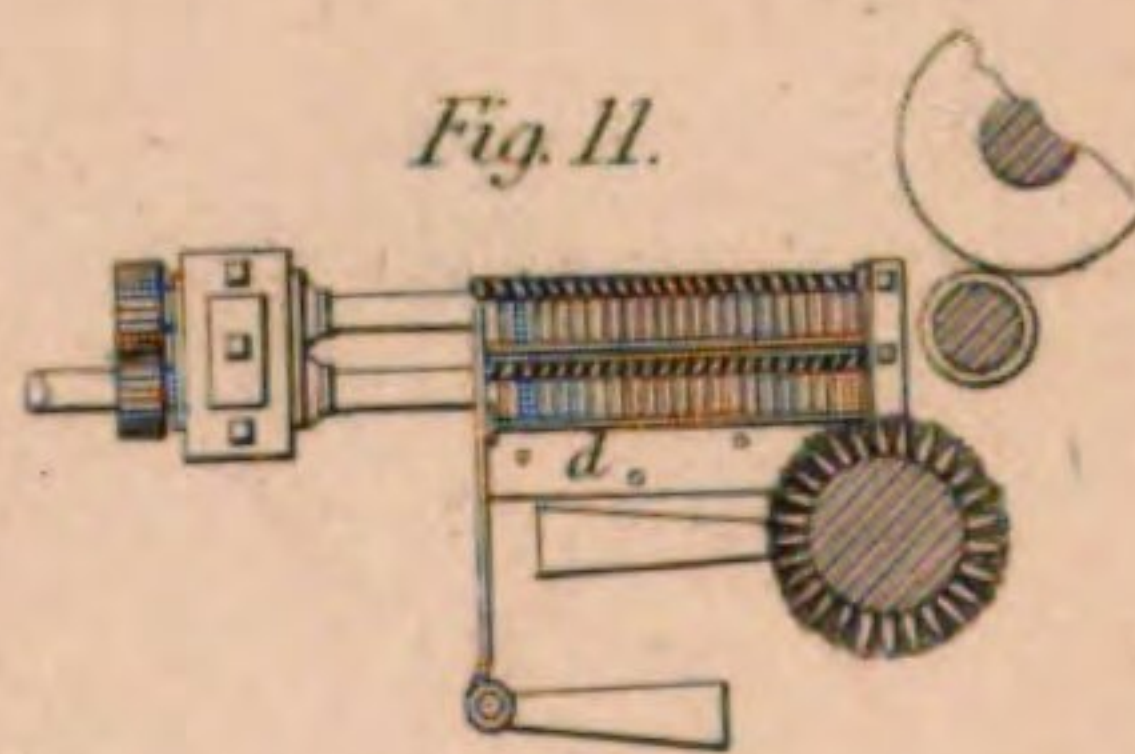
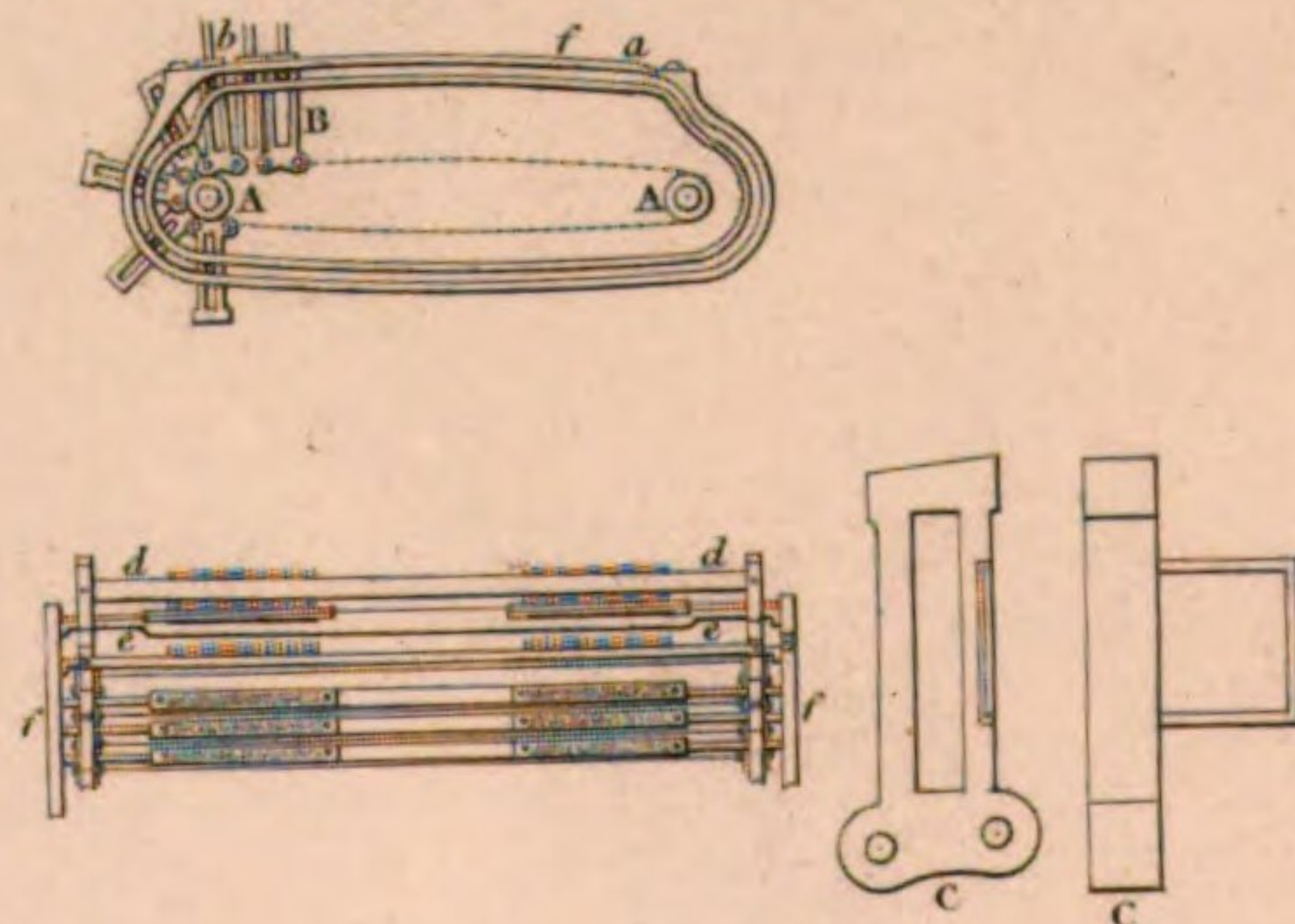


Fig. 10.



SMITH'S NEW METHOD OF SPINNING COTTON YARN.

Fig. 1.

Side Elevation.

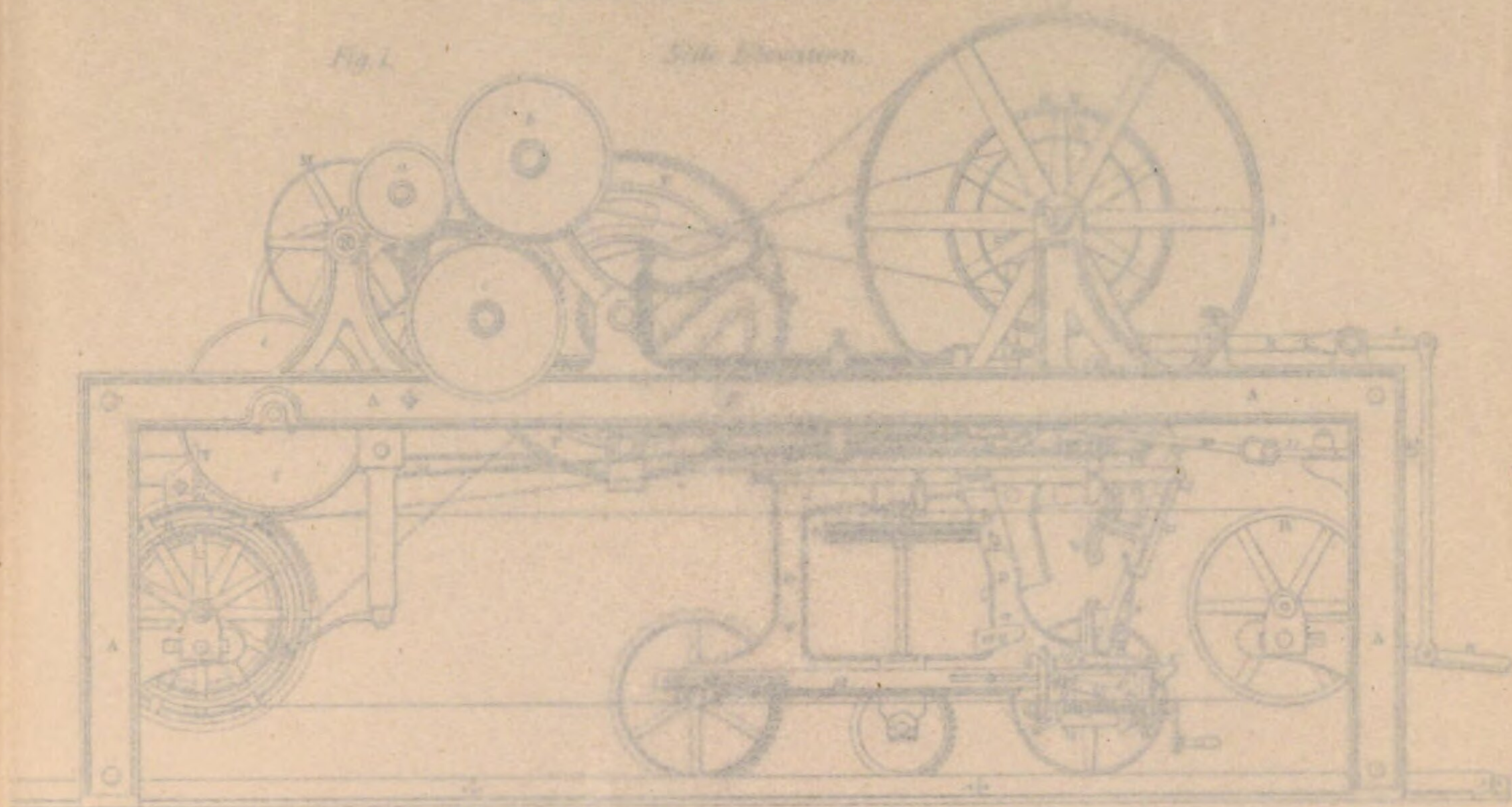


Fig. 3.

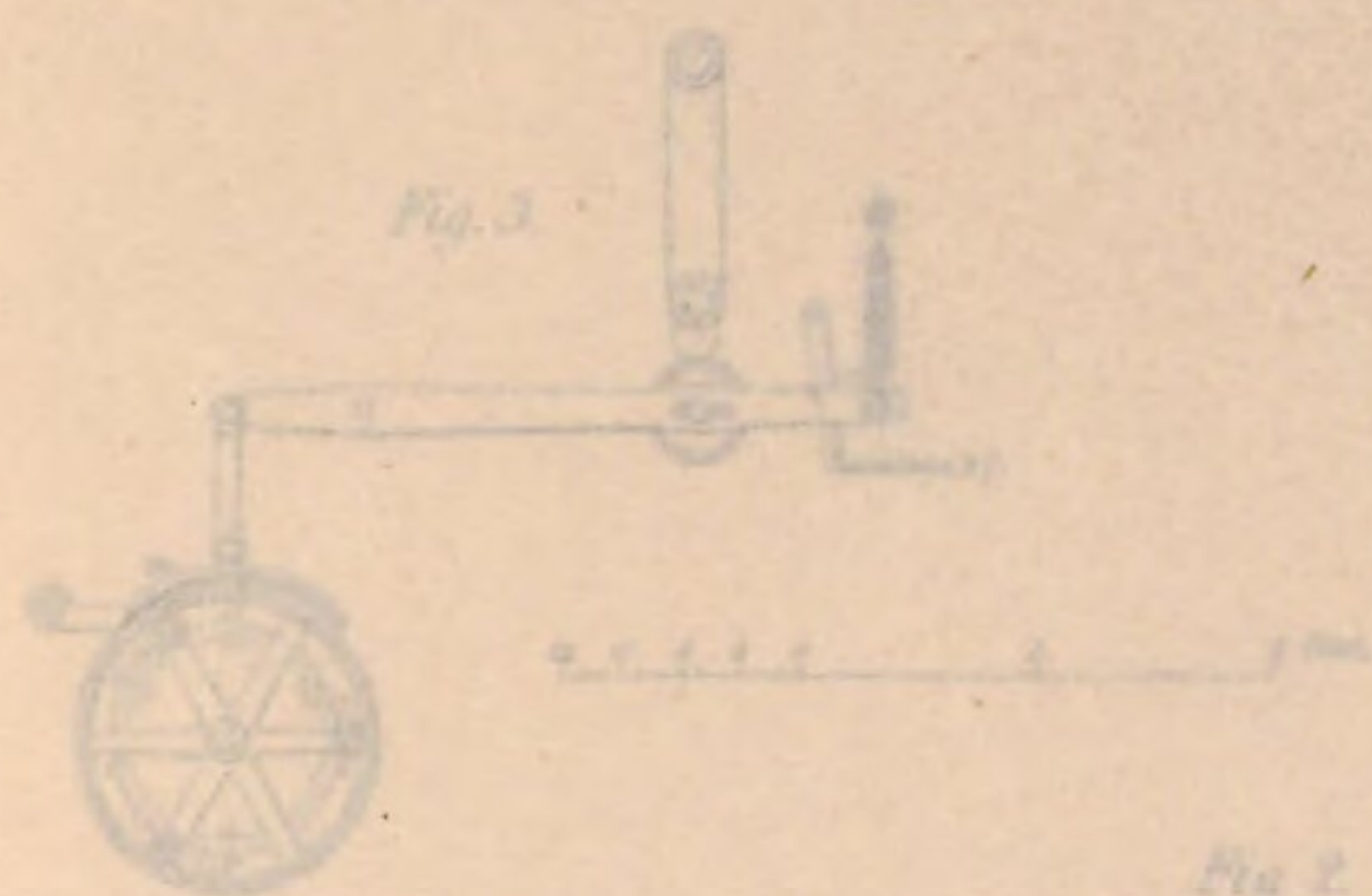


Fig. 4.

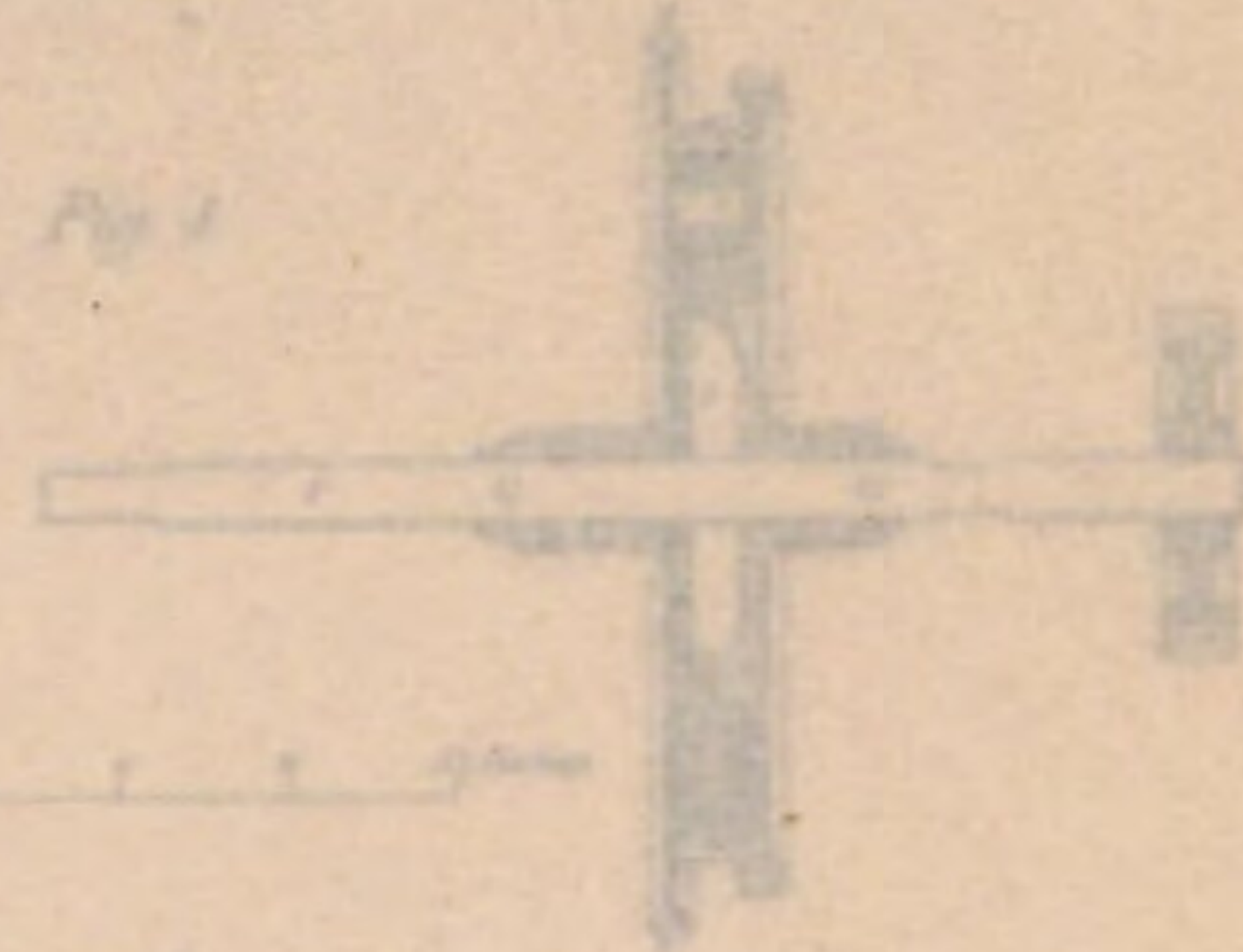
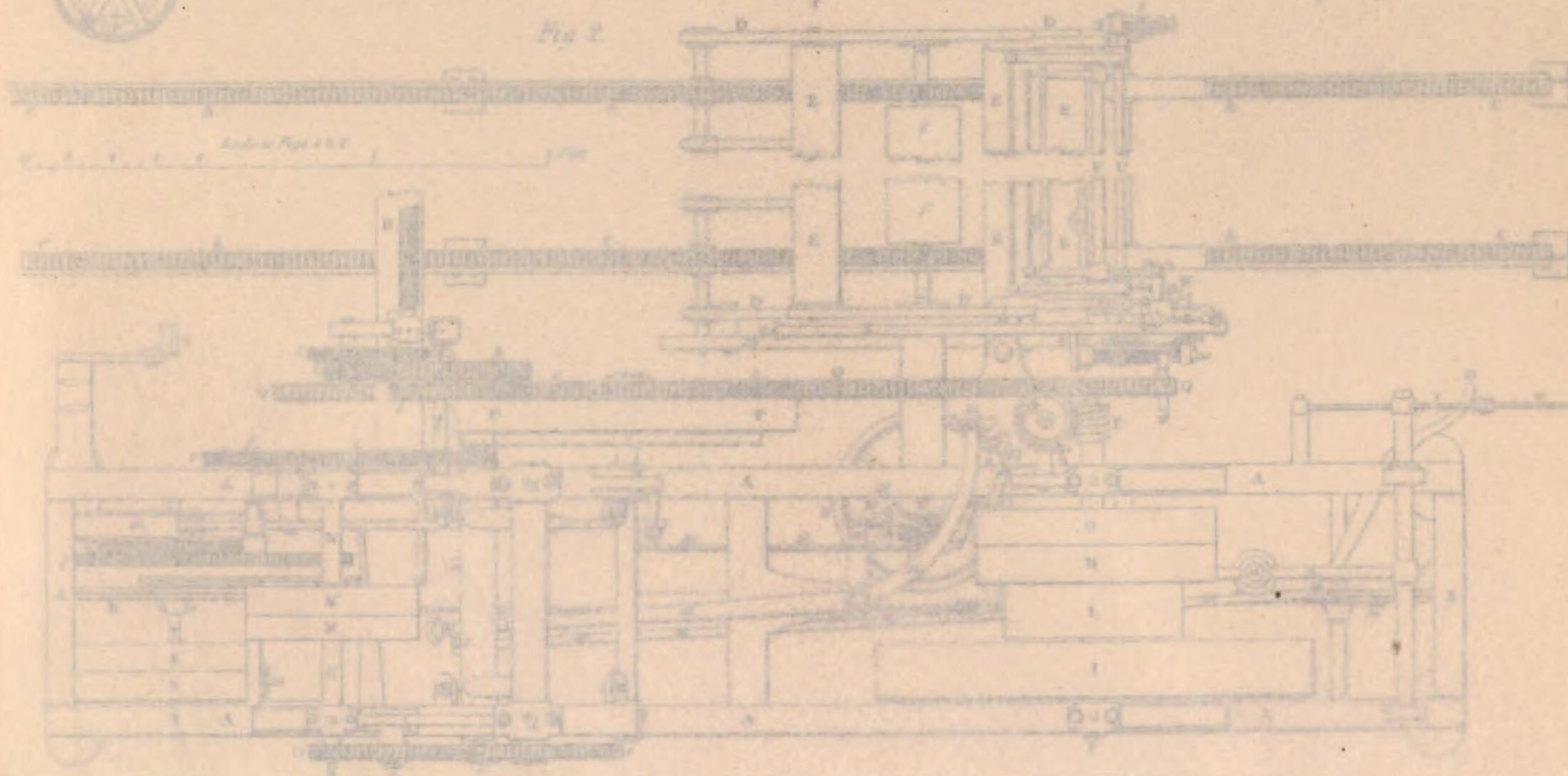
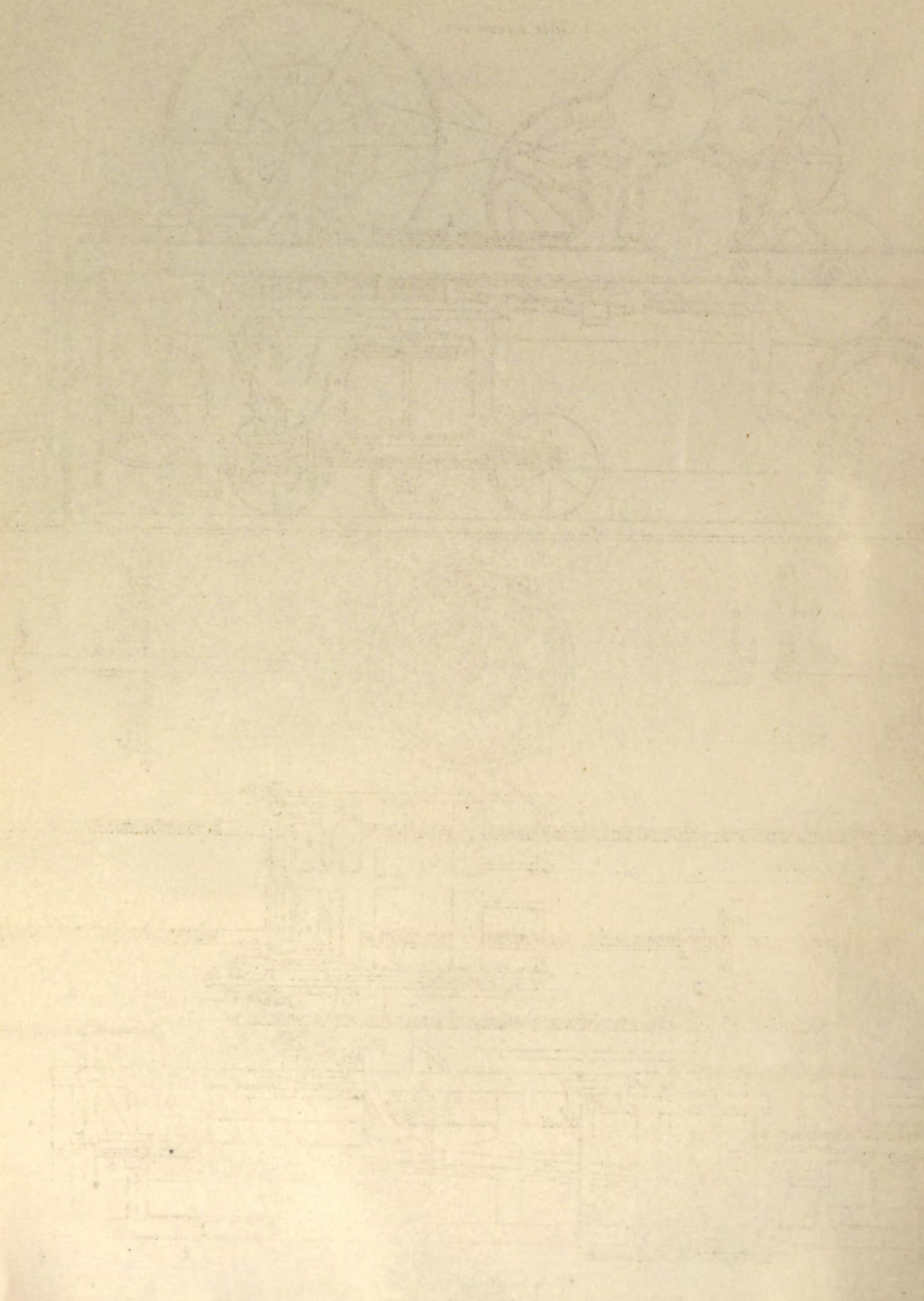


Fig. 2.



Plan or Birds-eye View.



SMITH'S SELF ACTING COTTON MULE.

Fig. 1.

Side Elevation.

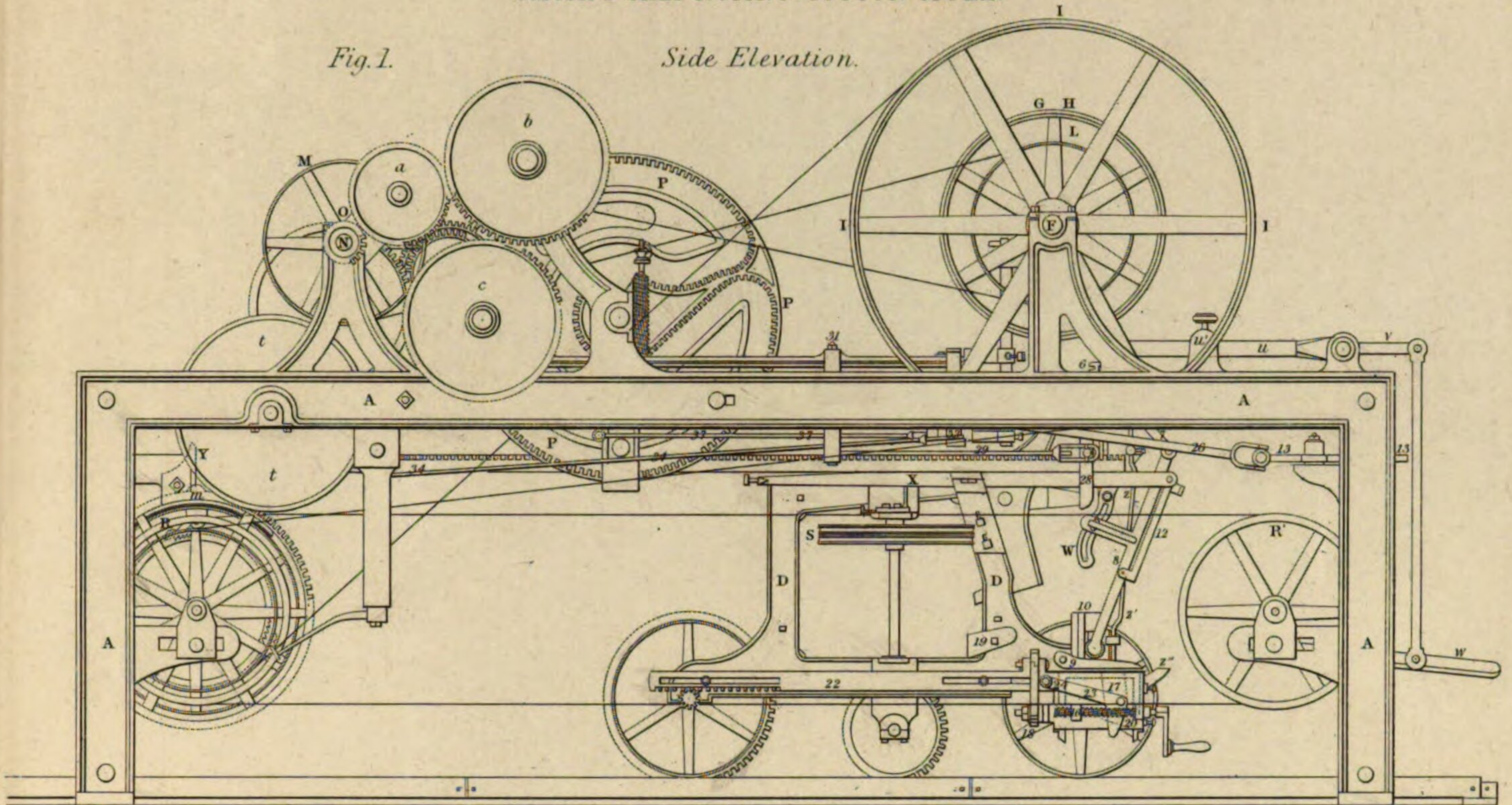


Fig. 3.

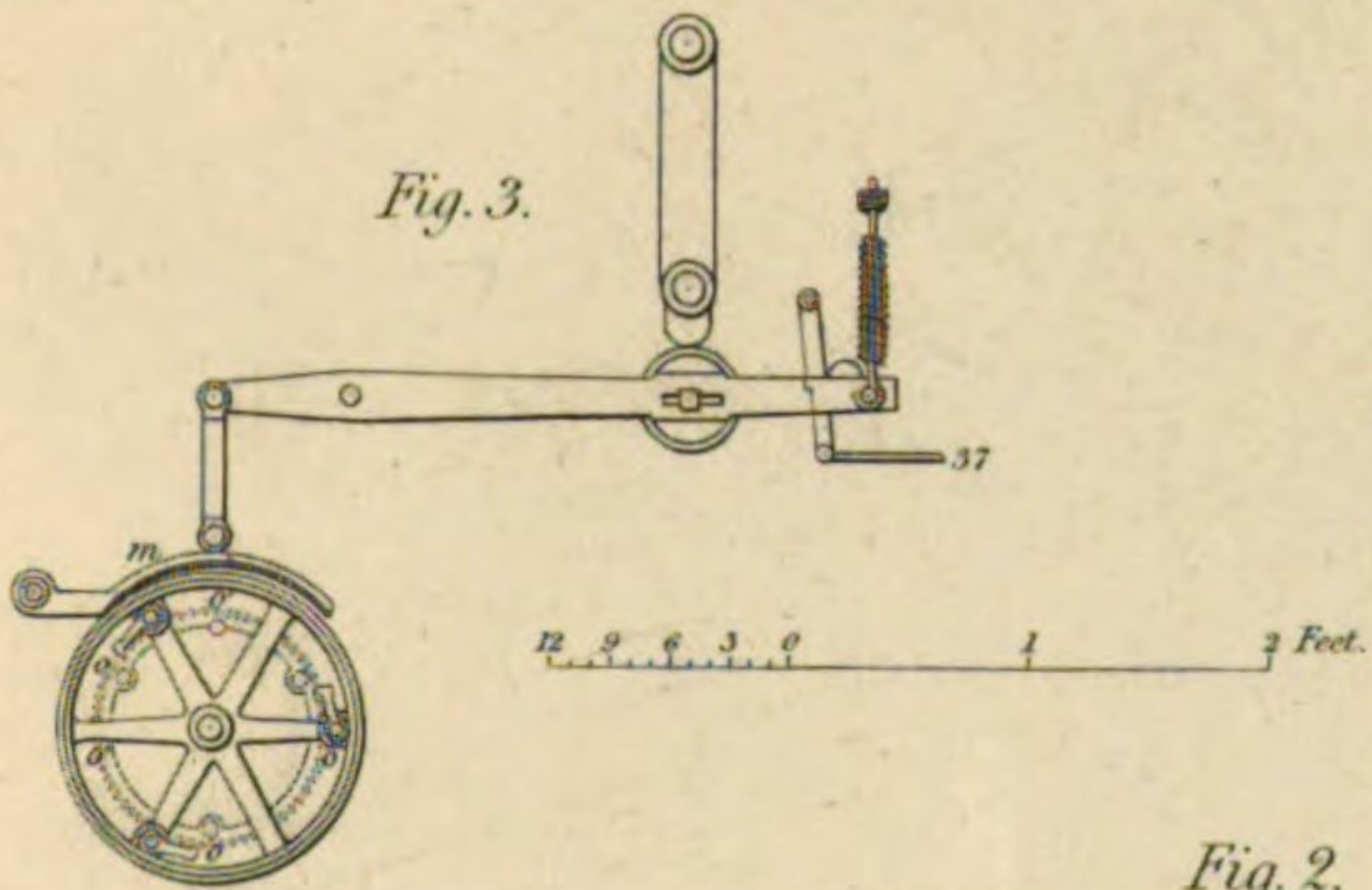


Fig. 4.

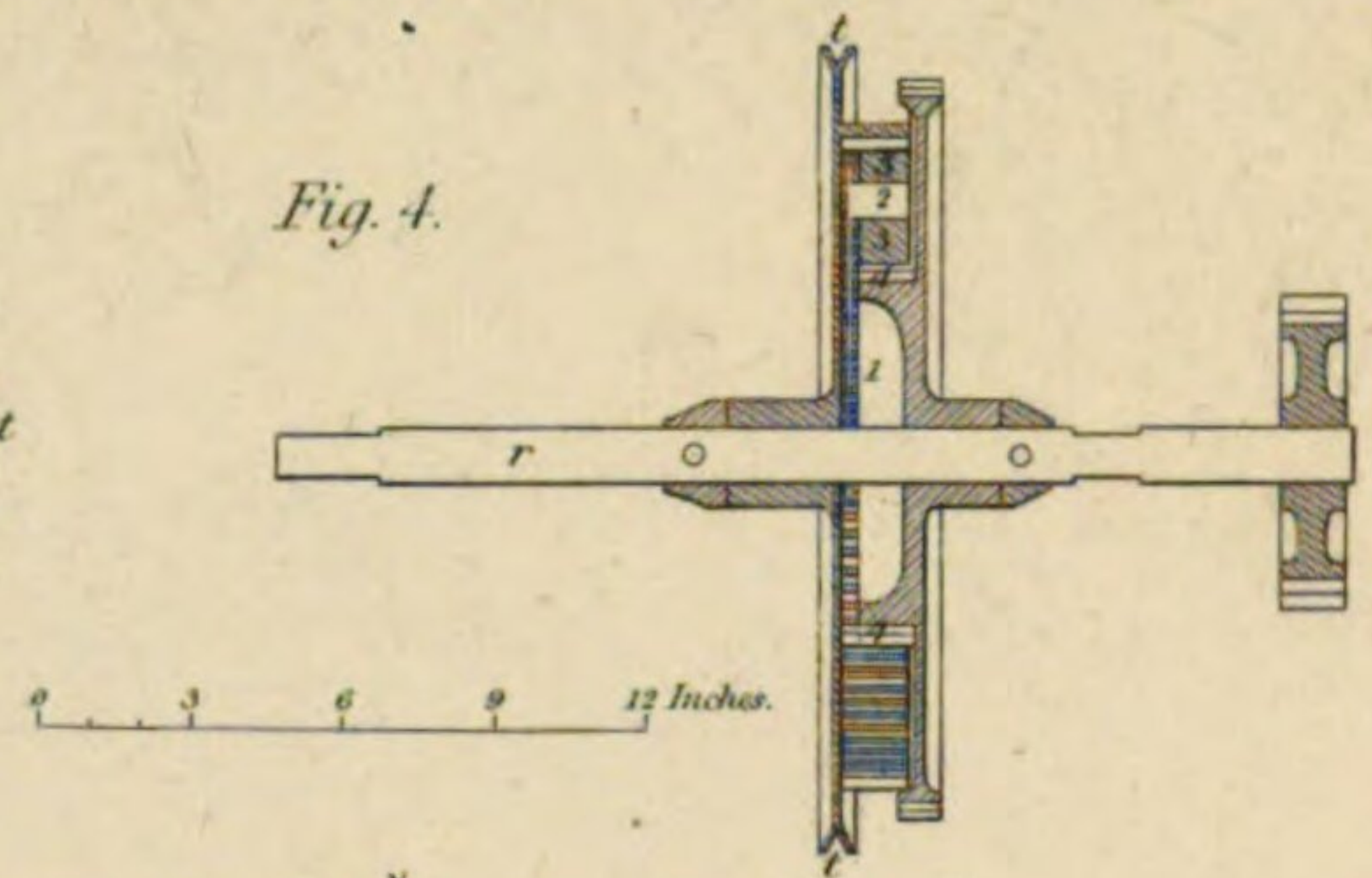
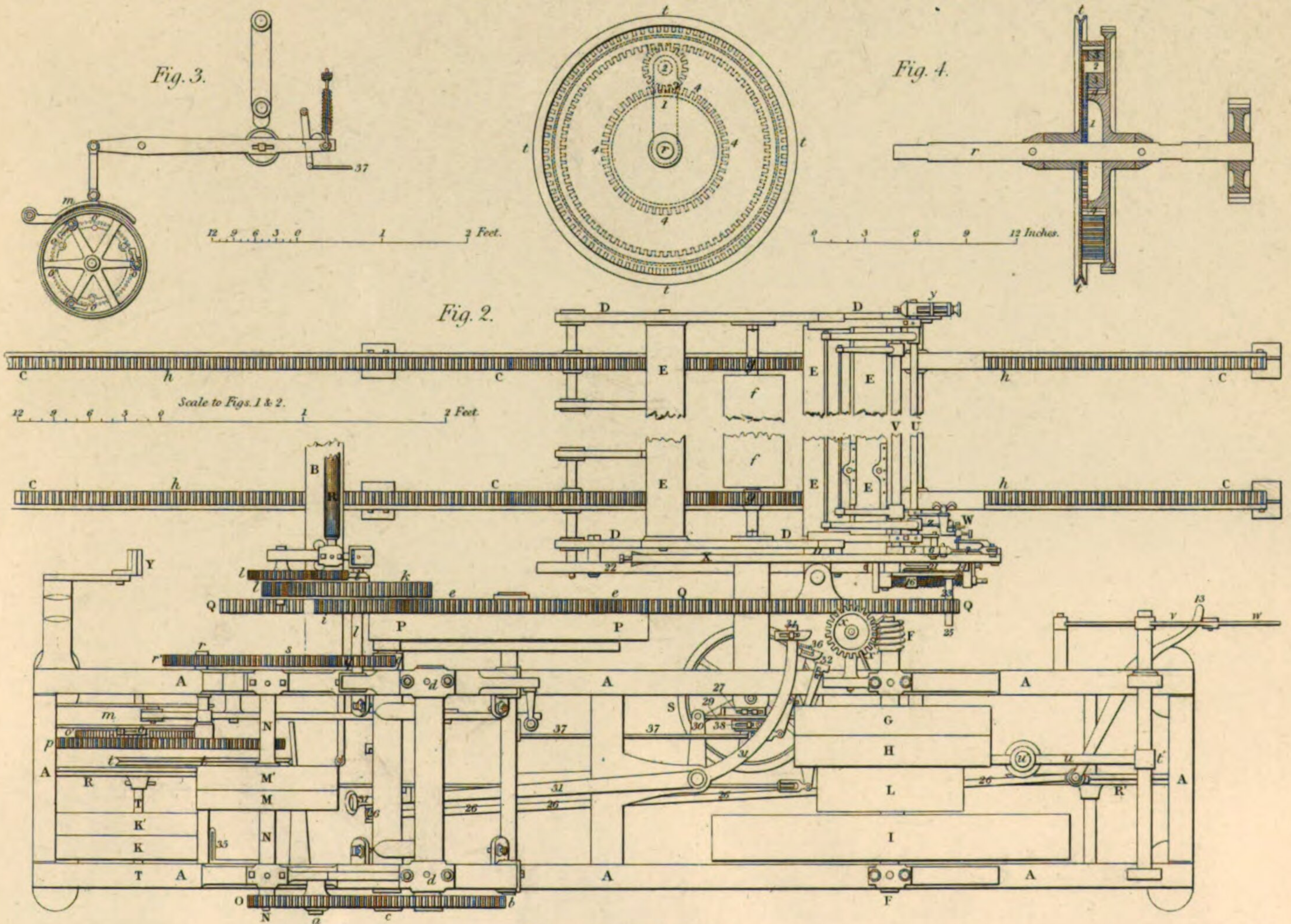
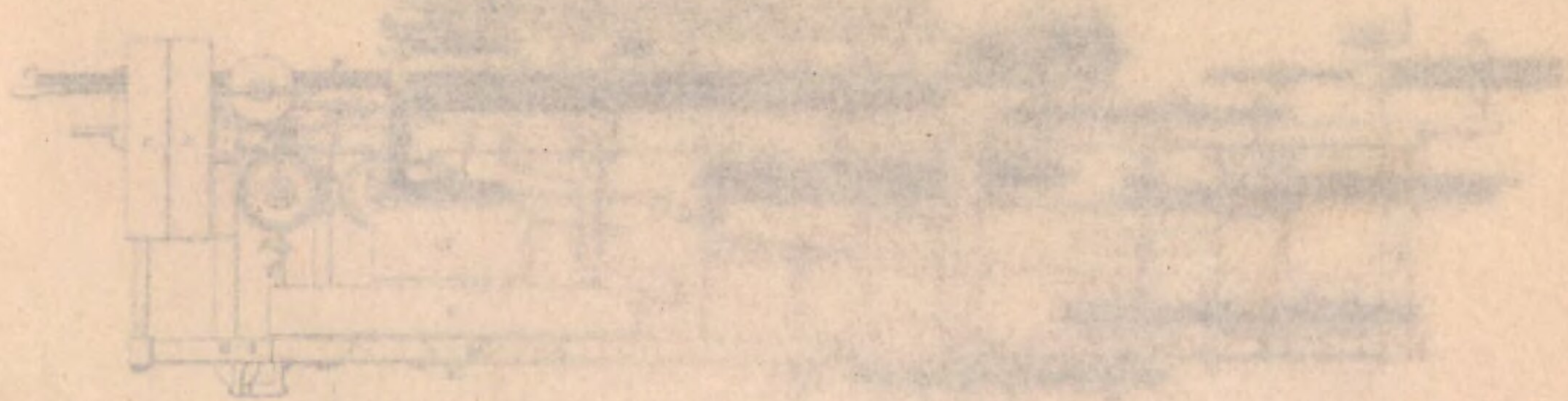
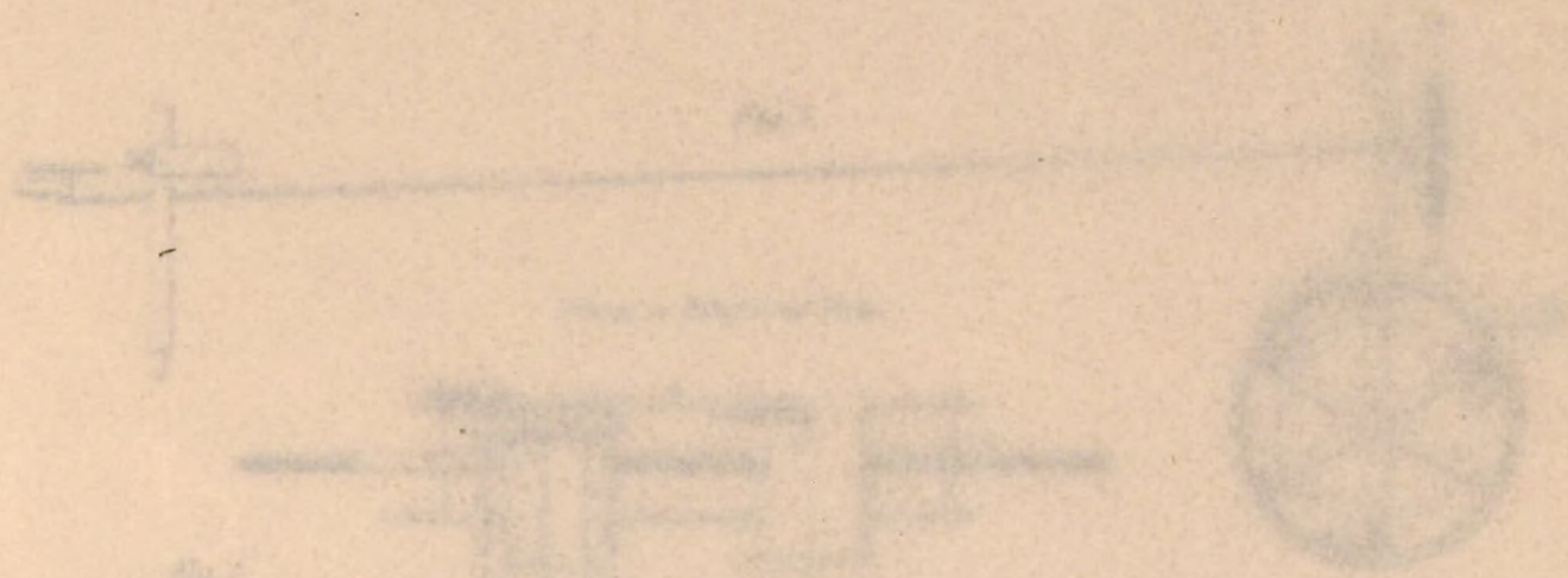


Fig. 2.



Plan or Bird's eye View.



SMITH'S SELF ACTING WOOLLEN MULE.

Side Elevation.

Fig. 1.

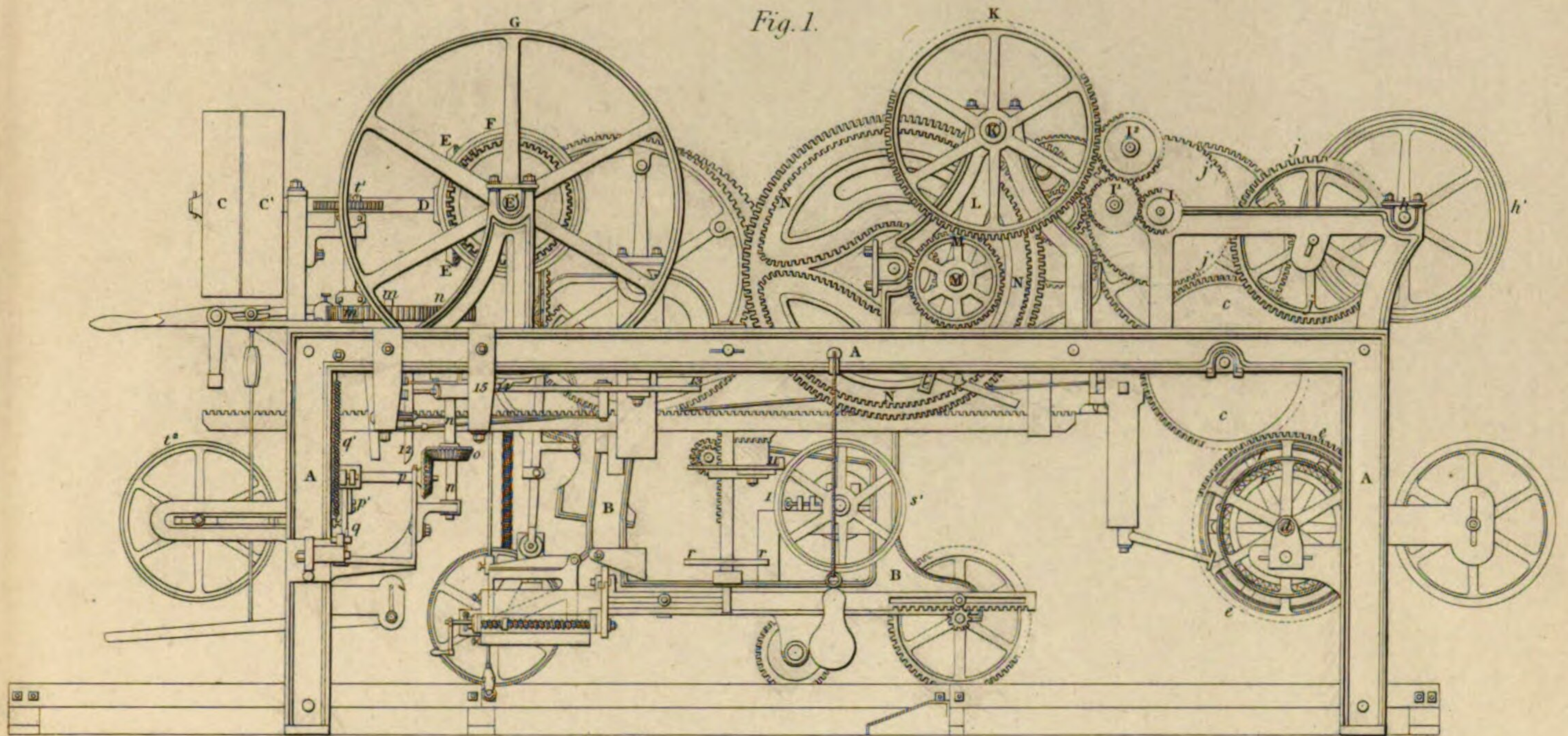
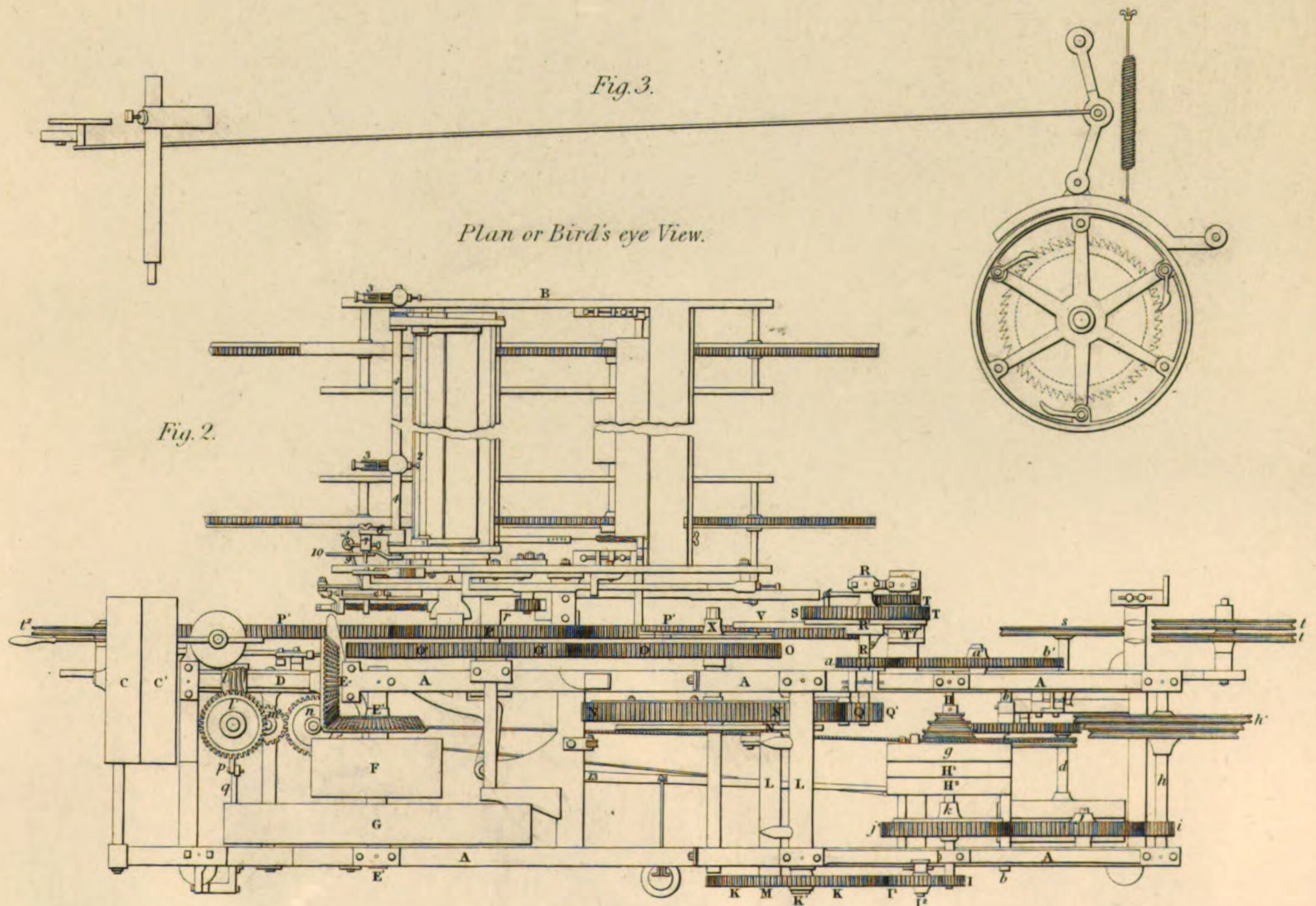


Fig. 3.

Plan or Bird's eye View.



174

Front Elevation.

Fig. 1.

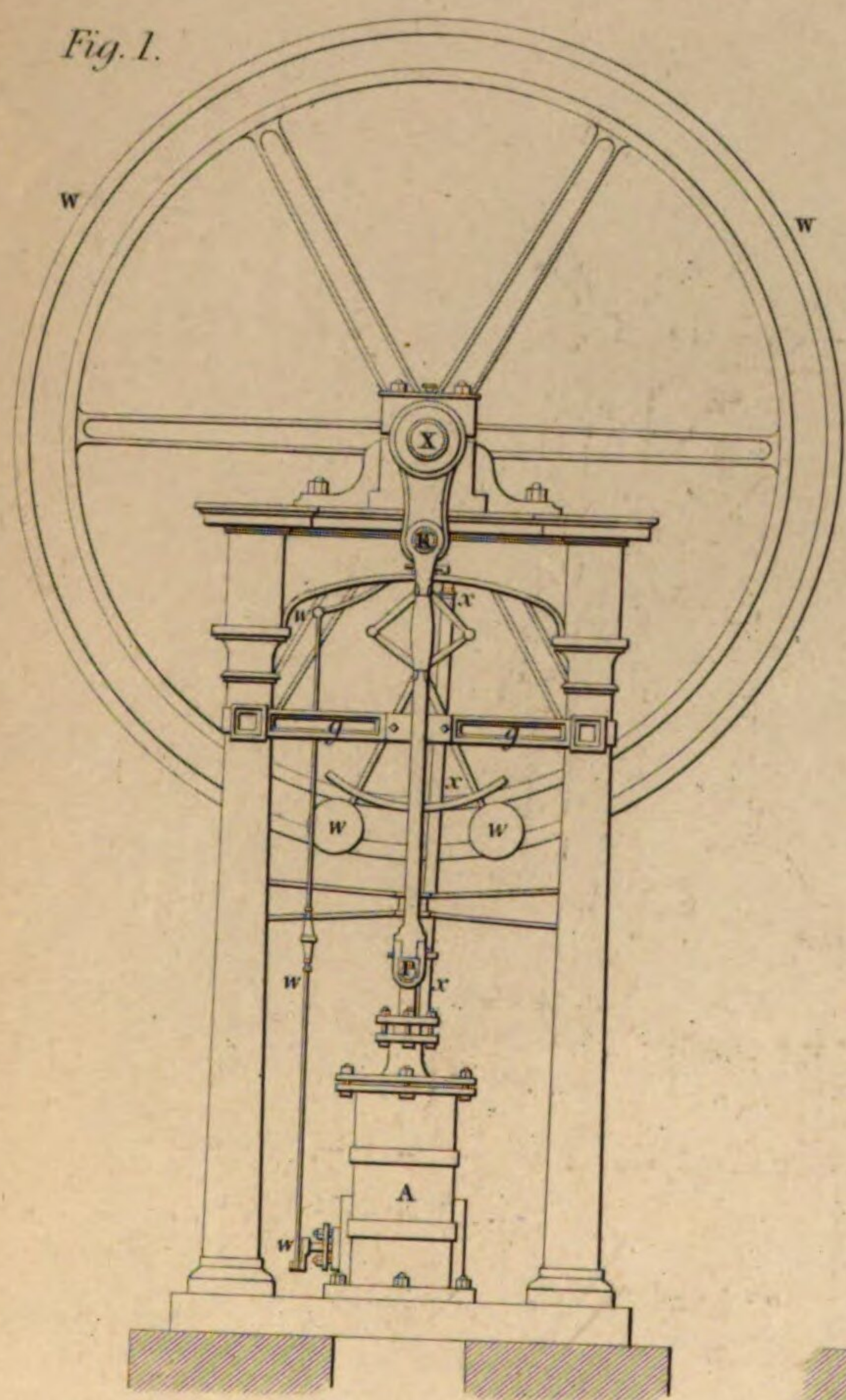


Fig. 2.

Side Elevation.

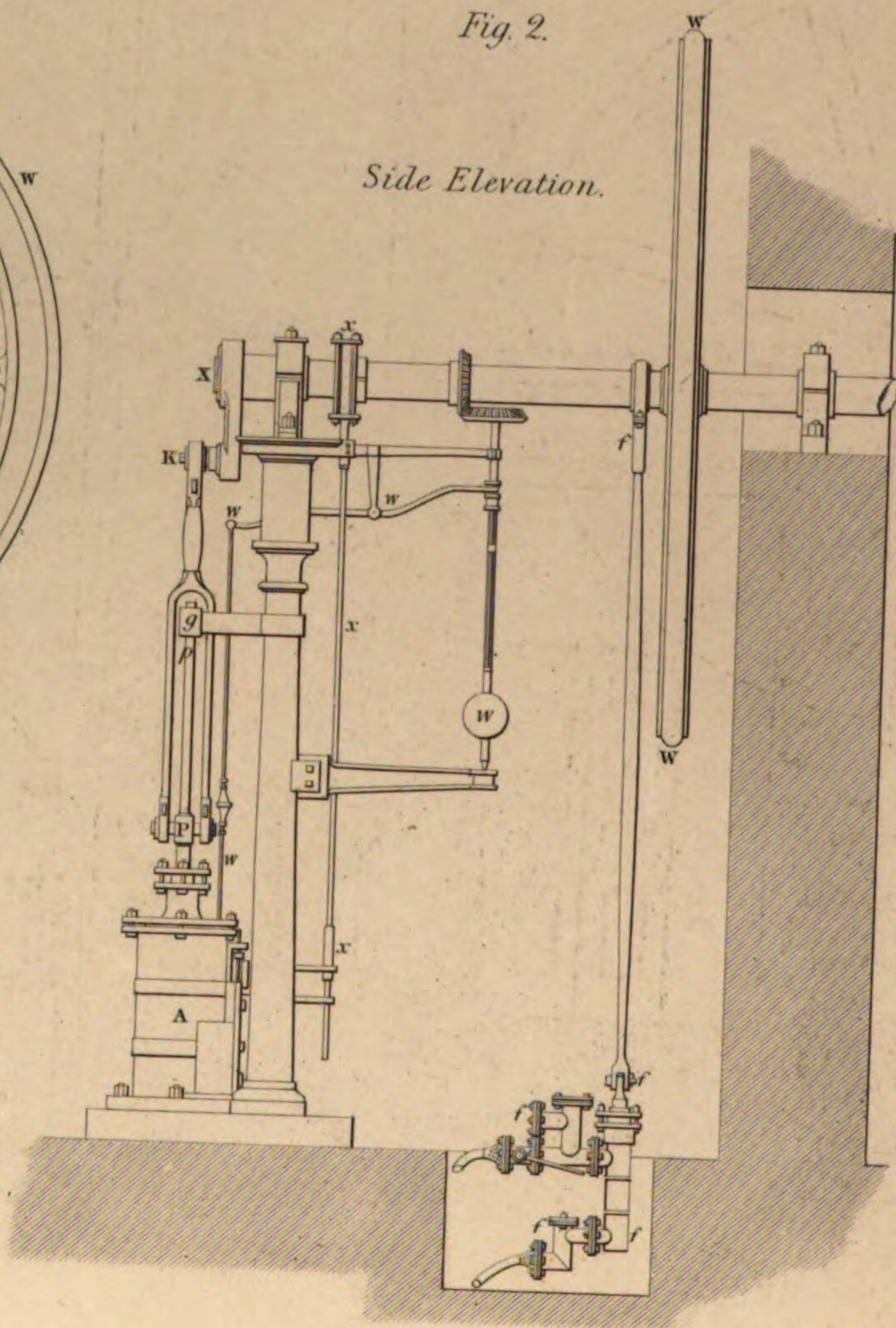
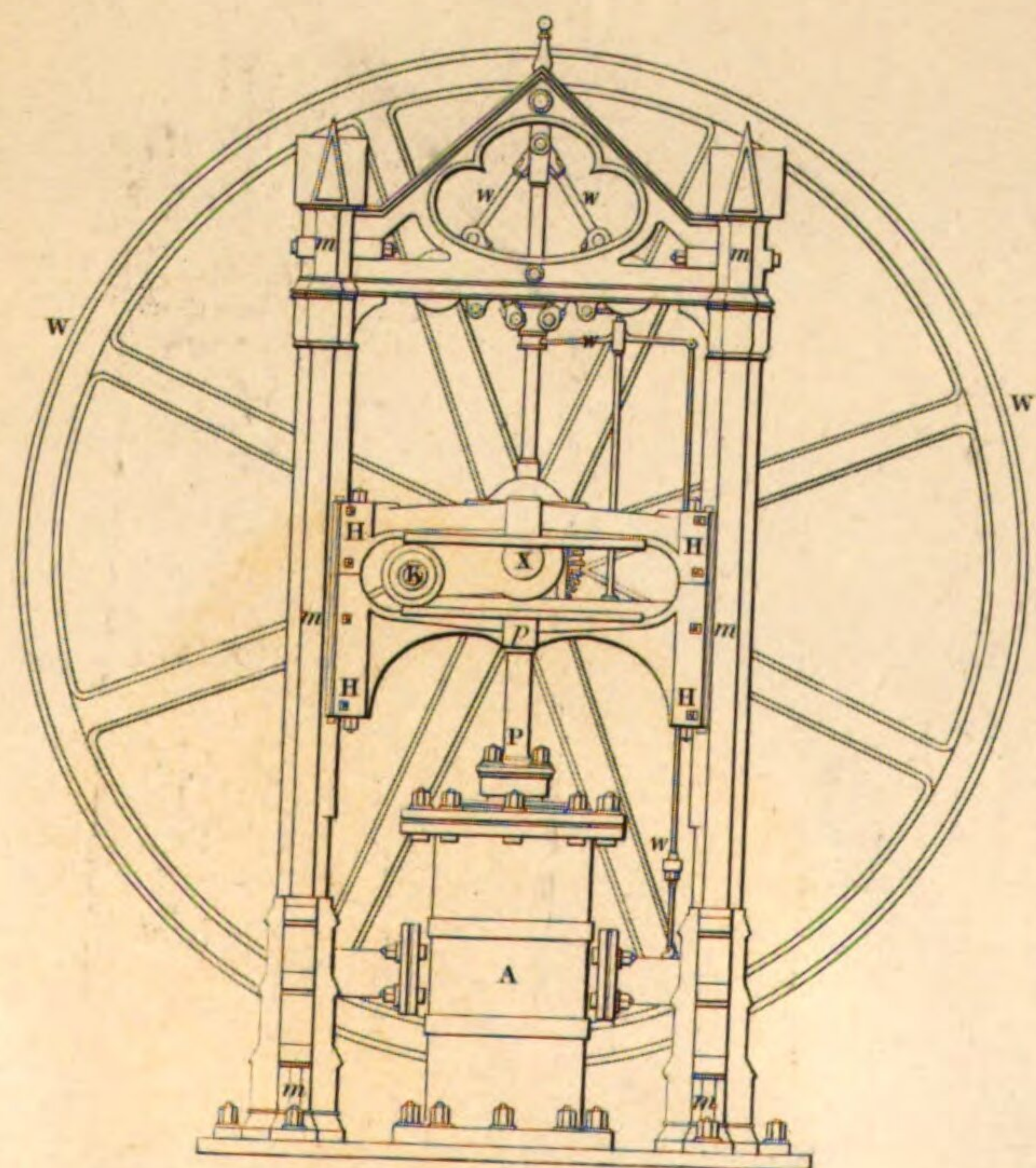
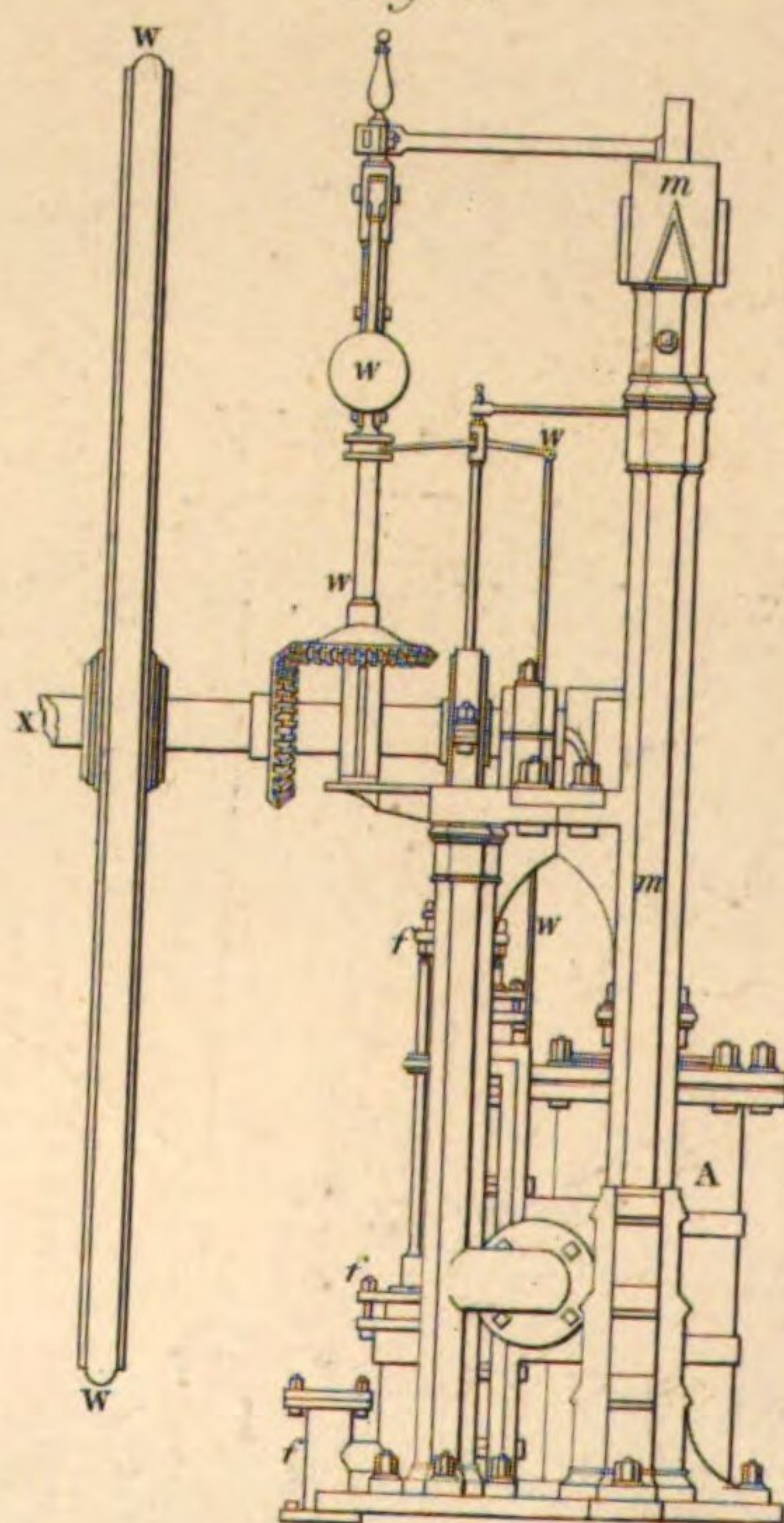


Fig. 3.



Front Elevation.

Fig. 4.



Side Elevation.

Fig. 7.

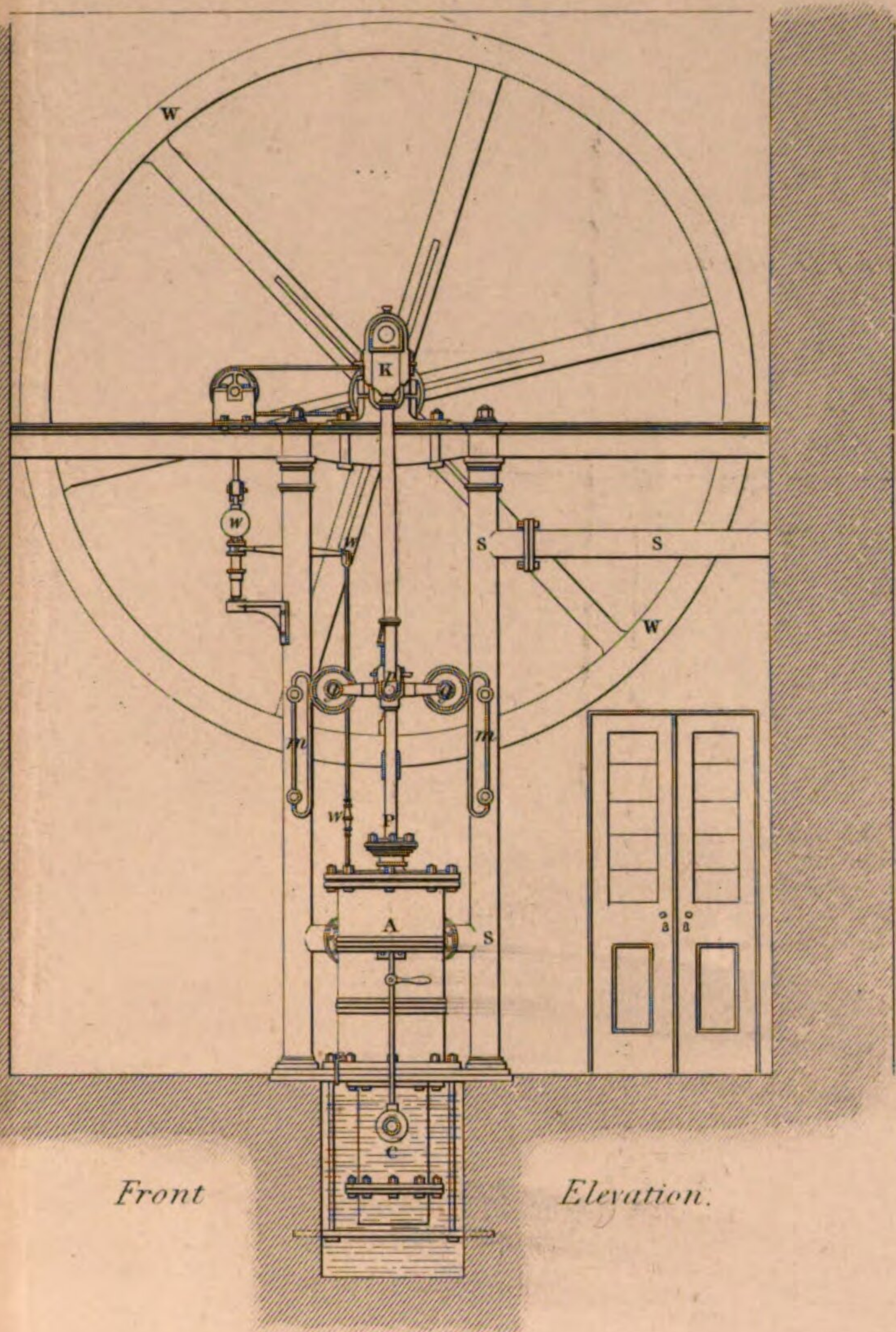


Fig. 8.

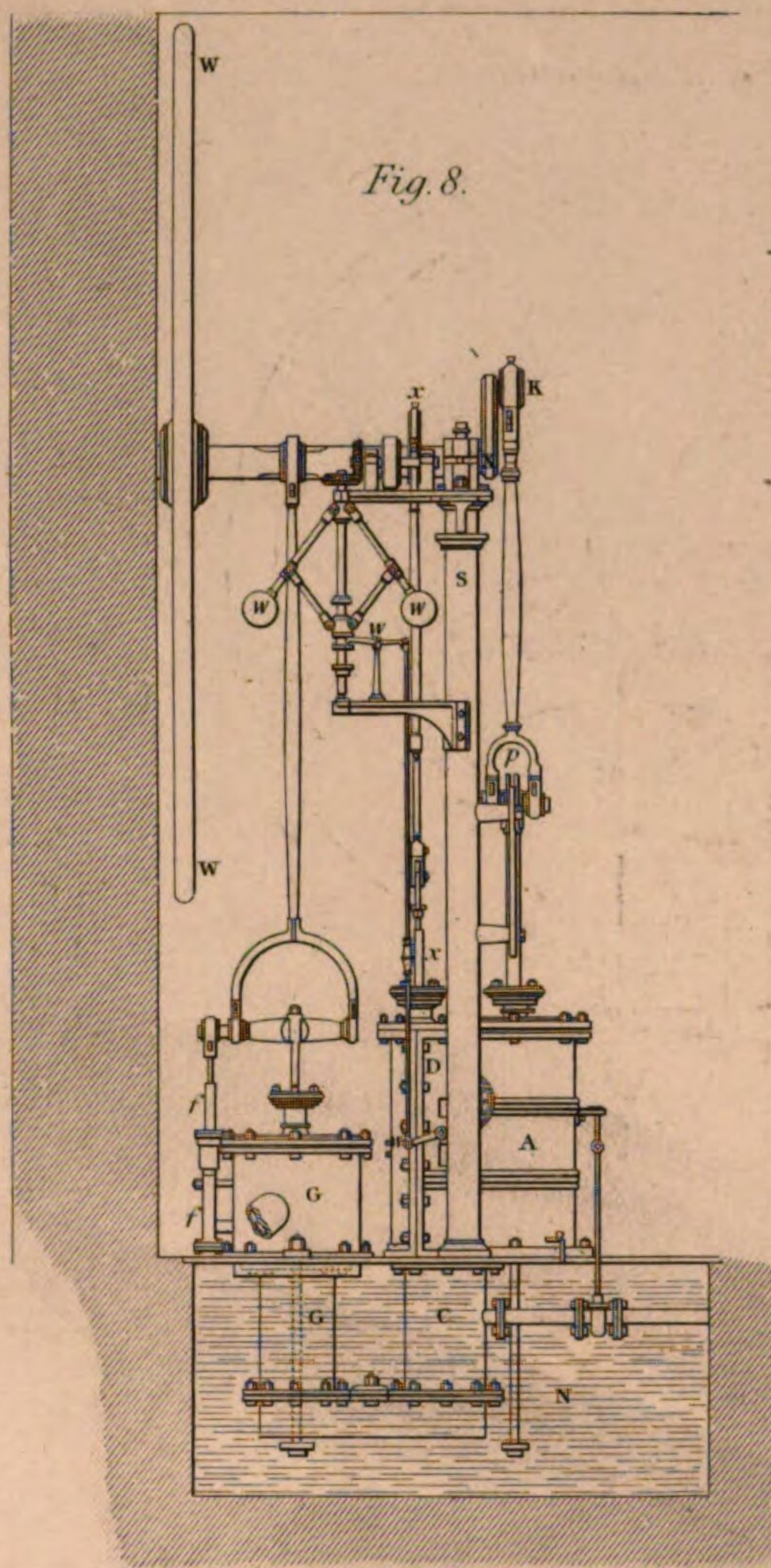


Fig. 5.

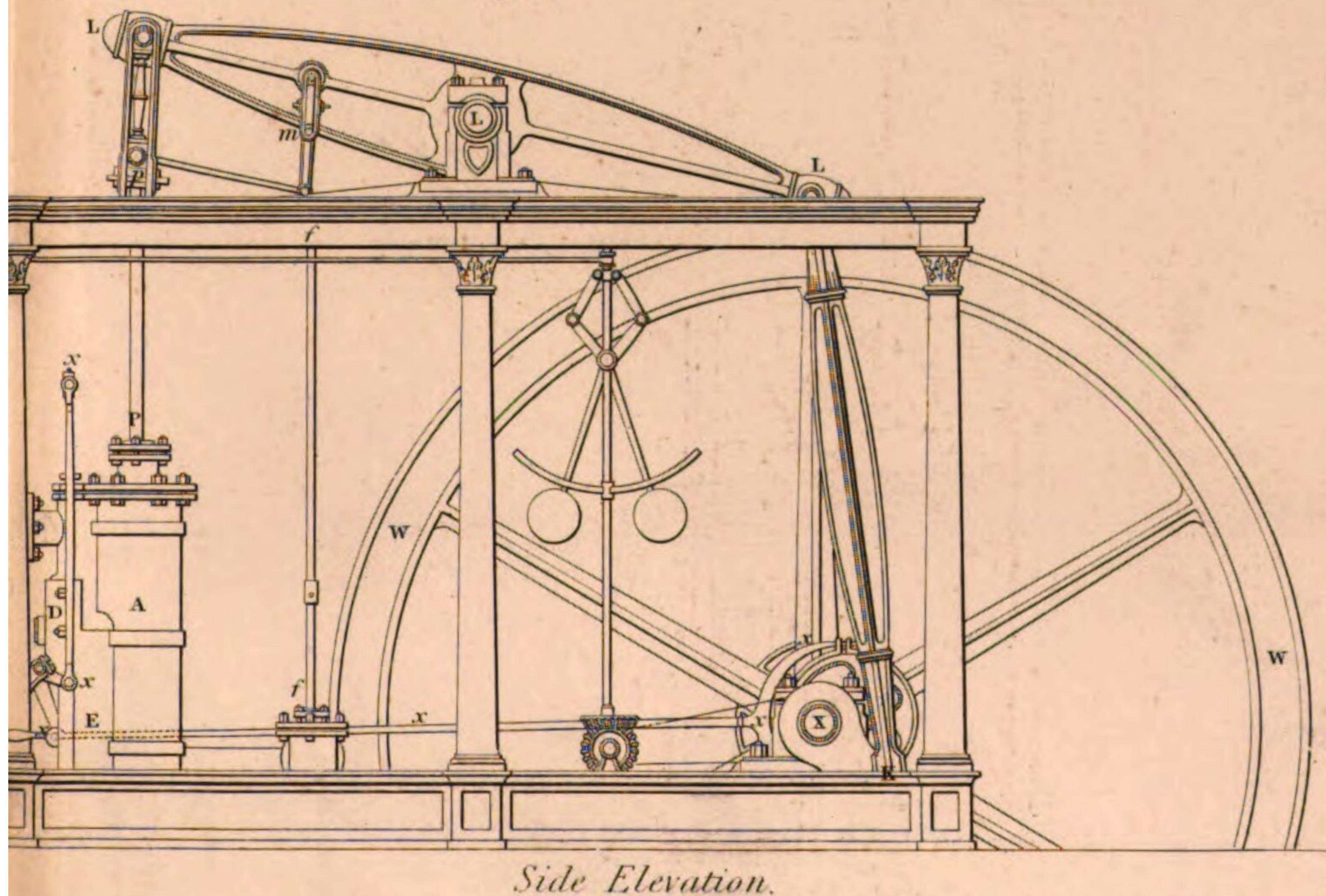
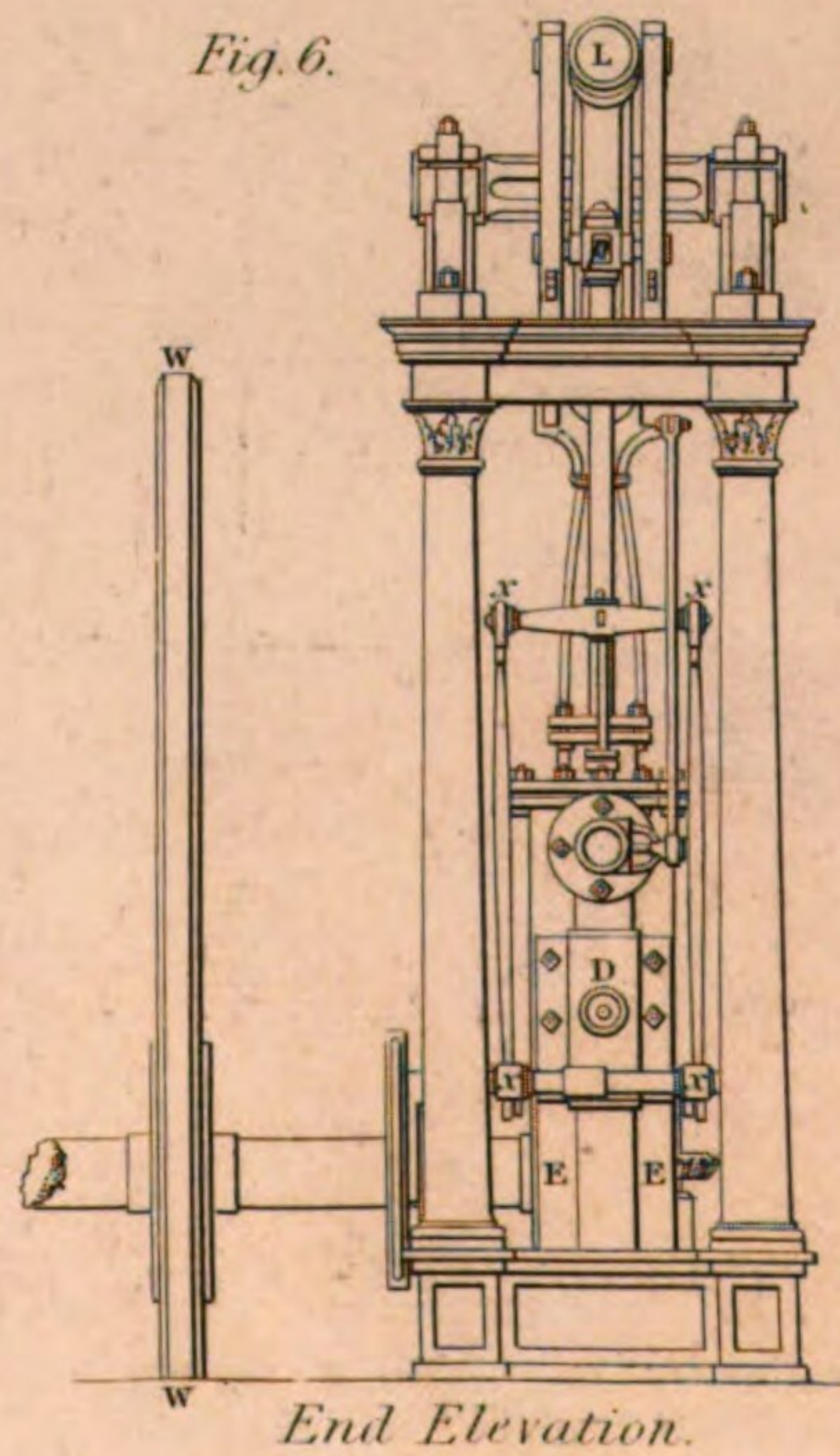
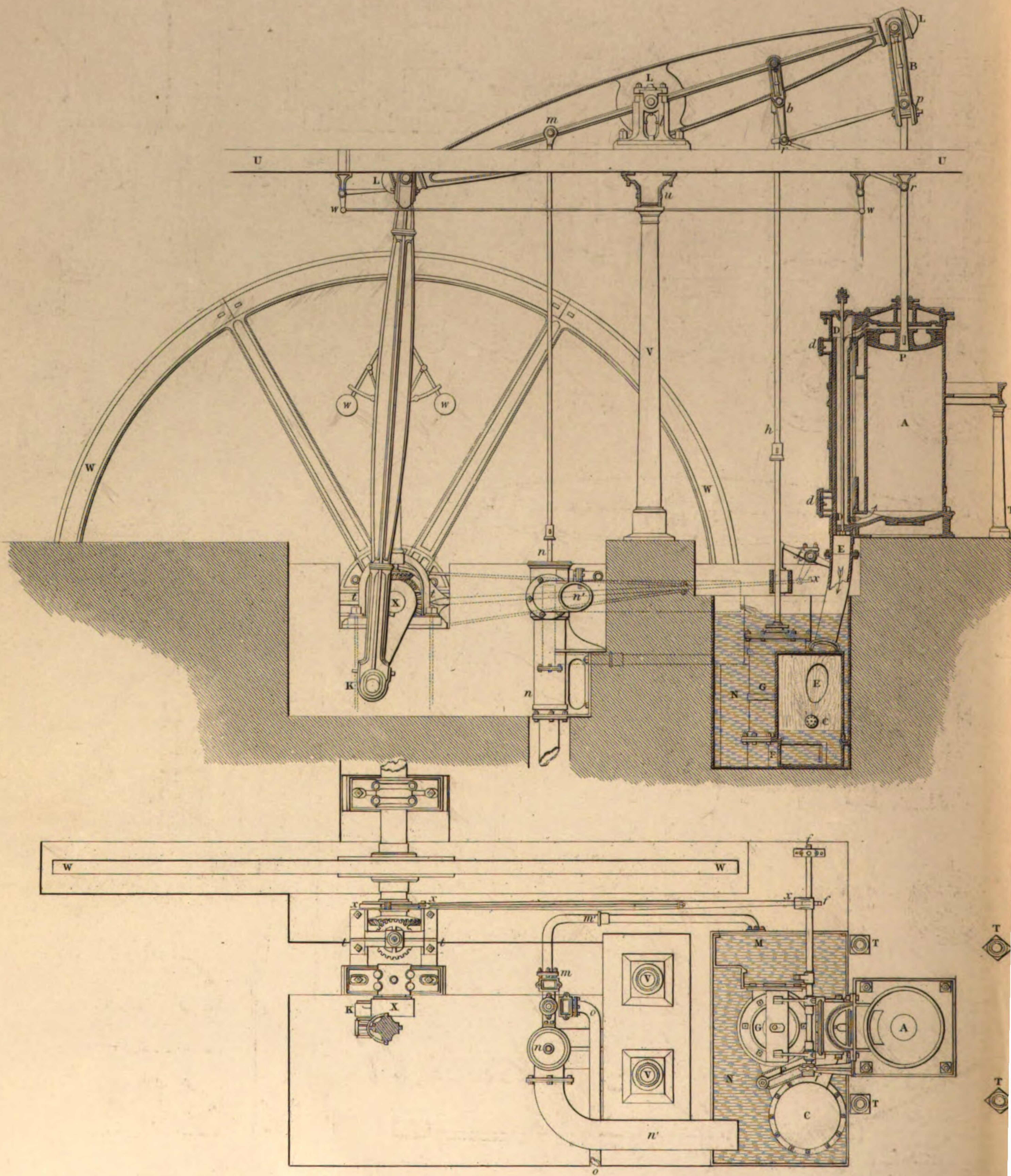
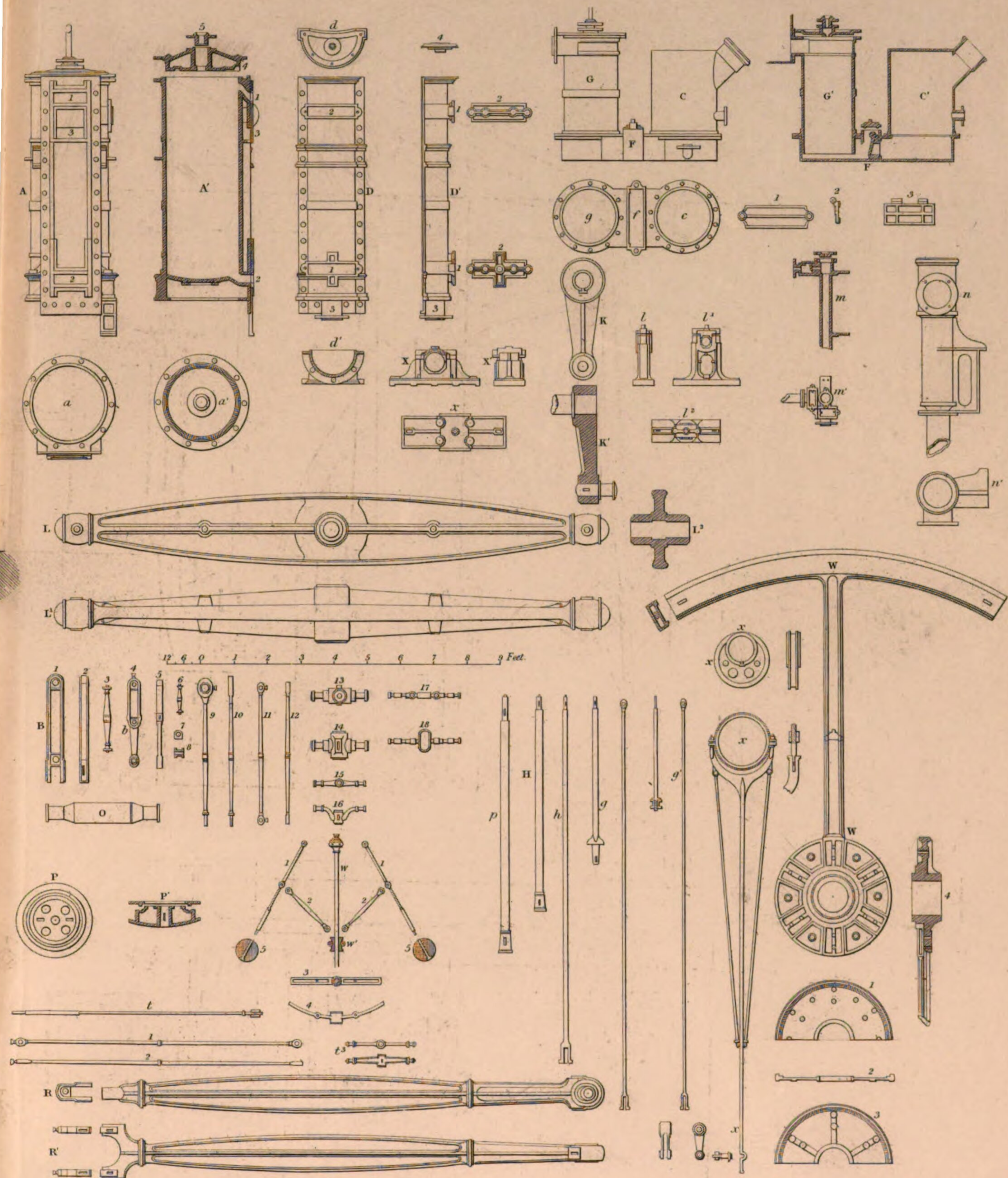
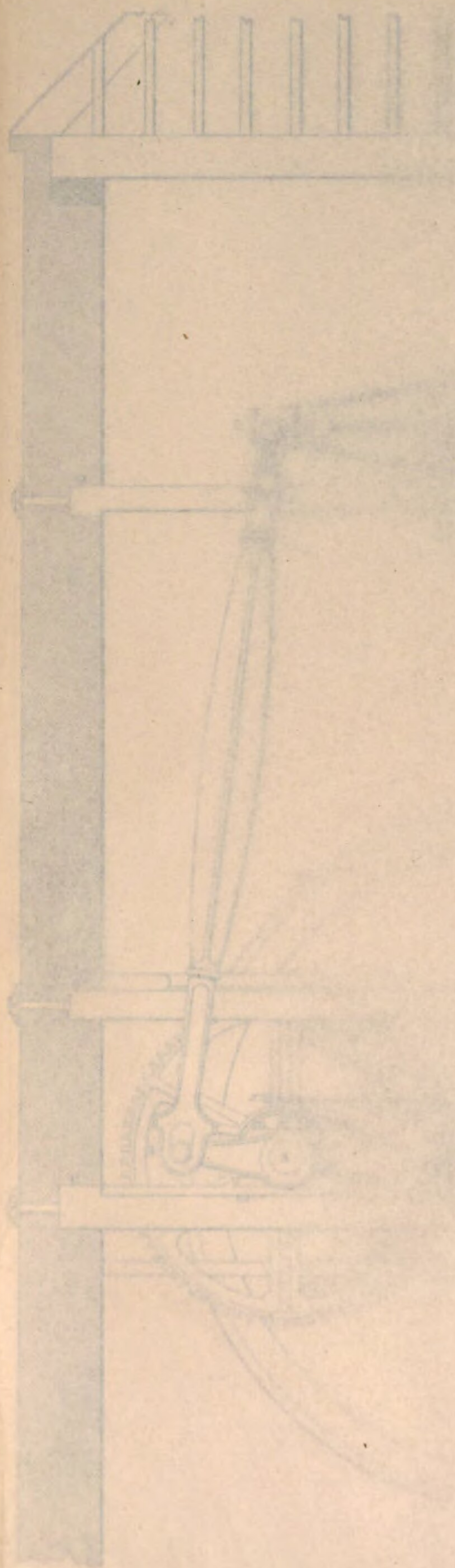


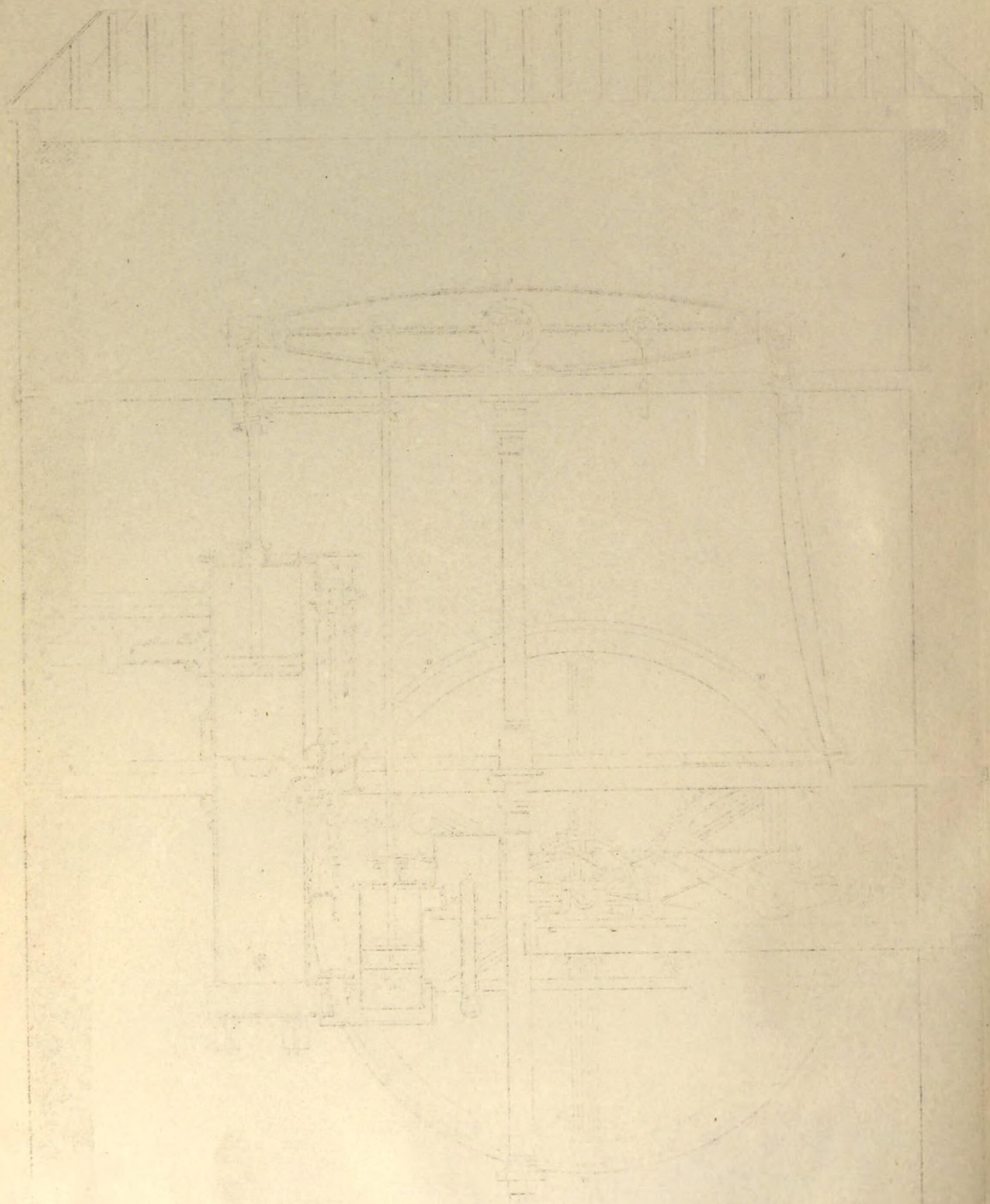
Fig. 6.

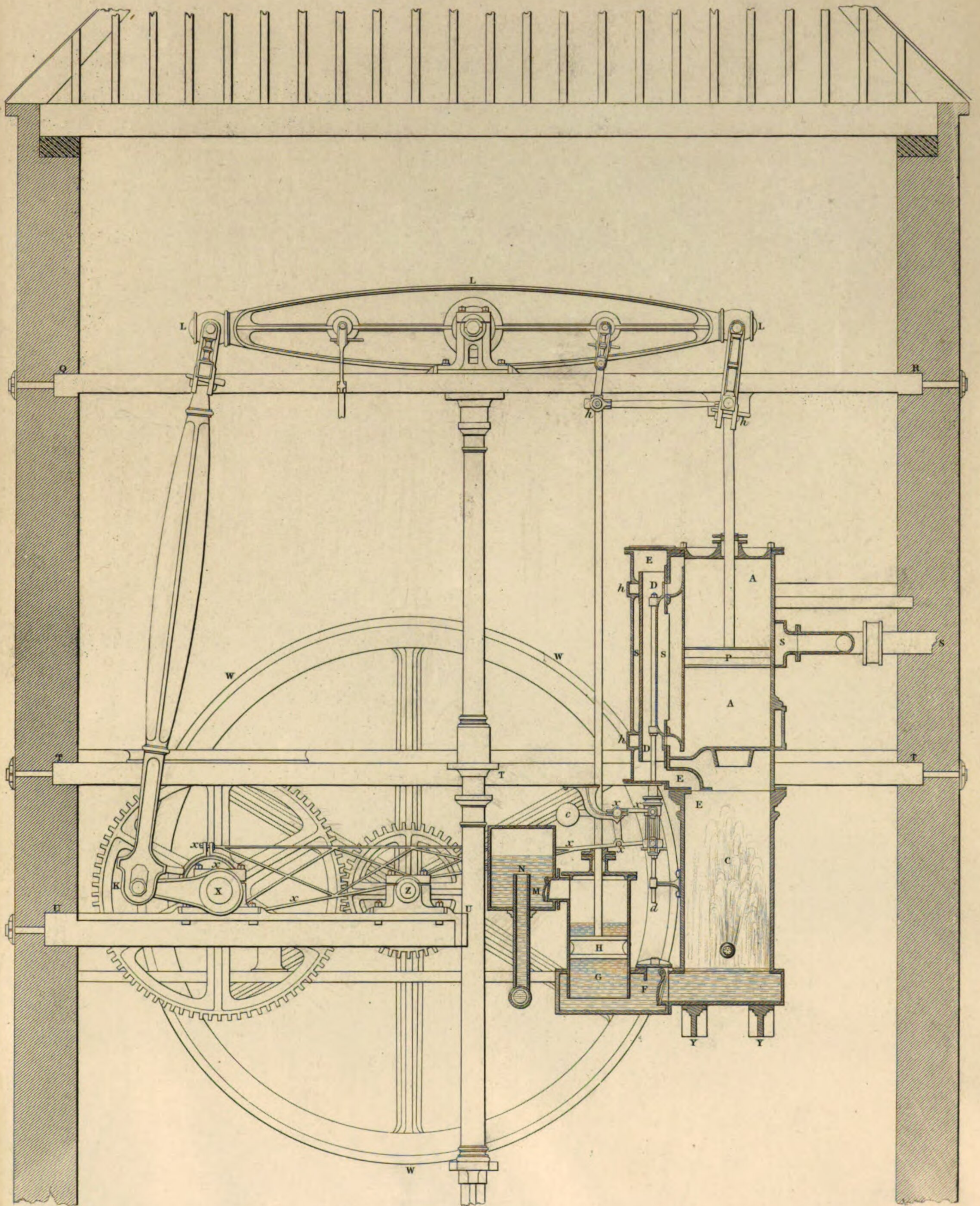








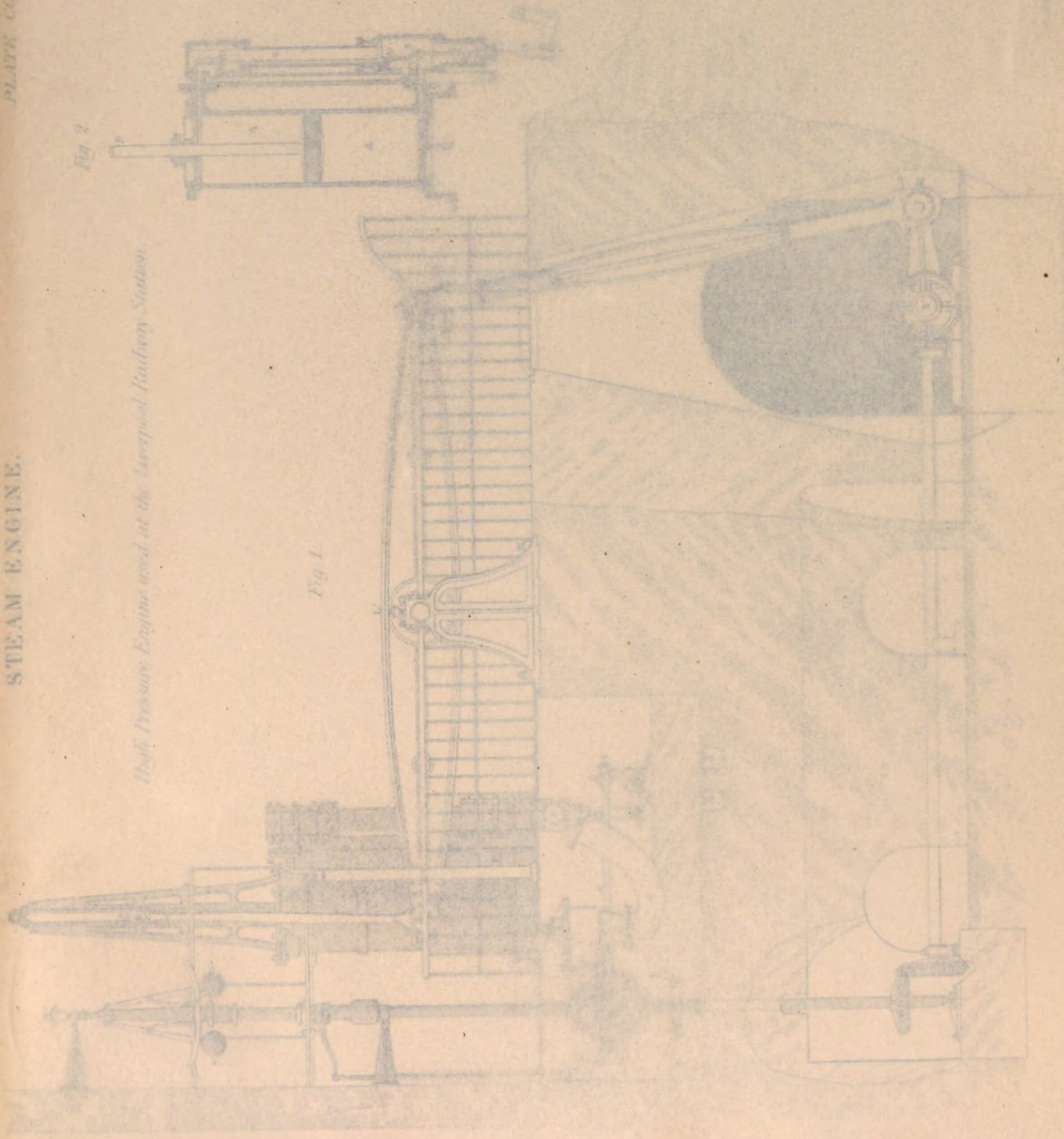




Multi Pressure Engine used at the Liverpool Railway Station.

Fig 1

Fig 2



High Pressure Engine used at the Liverpool Railway Station.

Fig. 1.

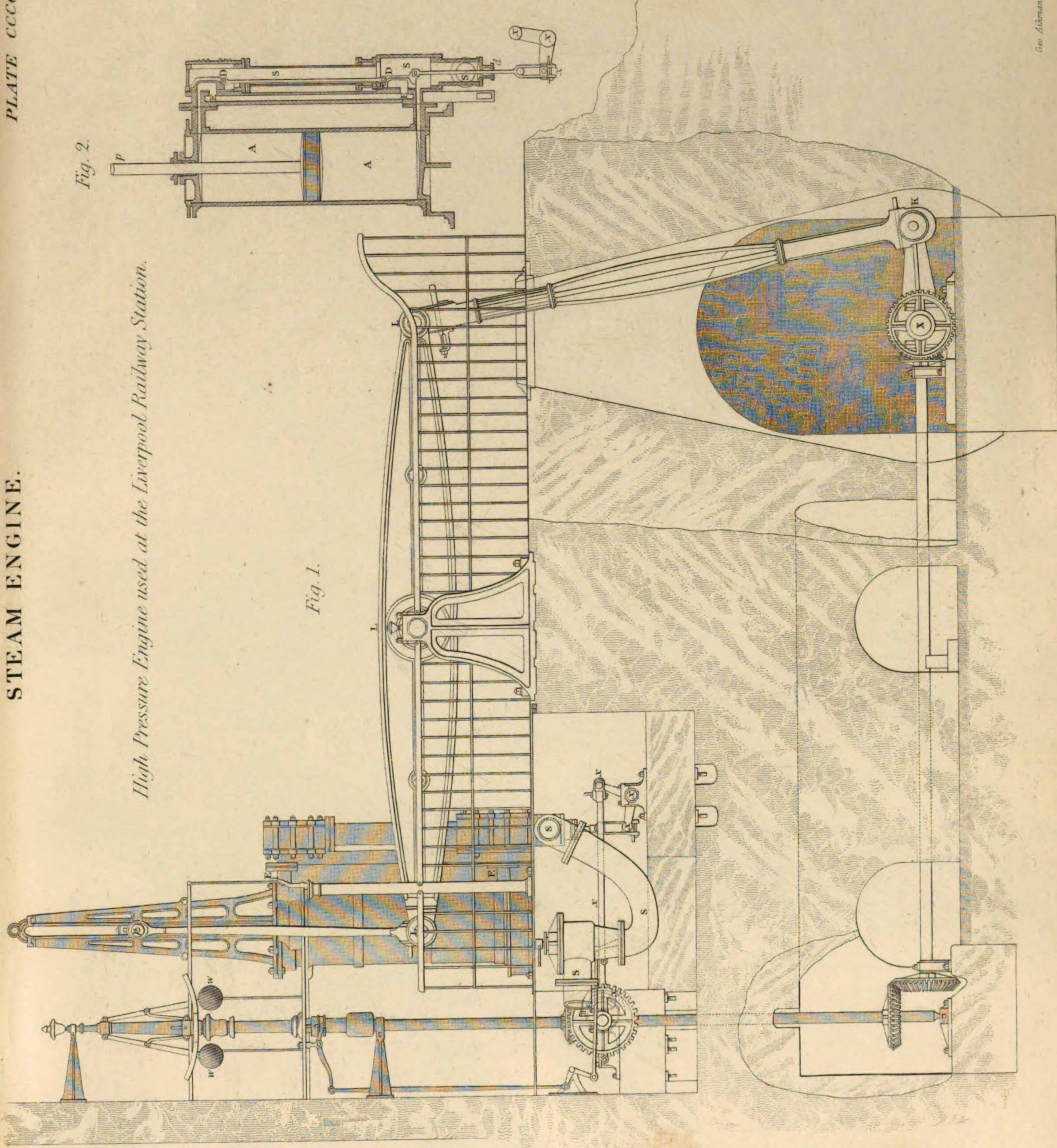
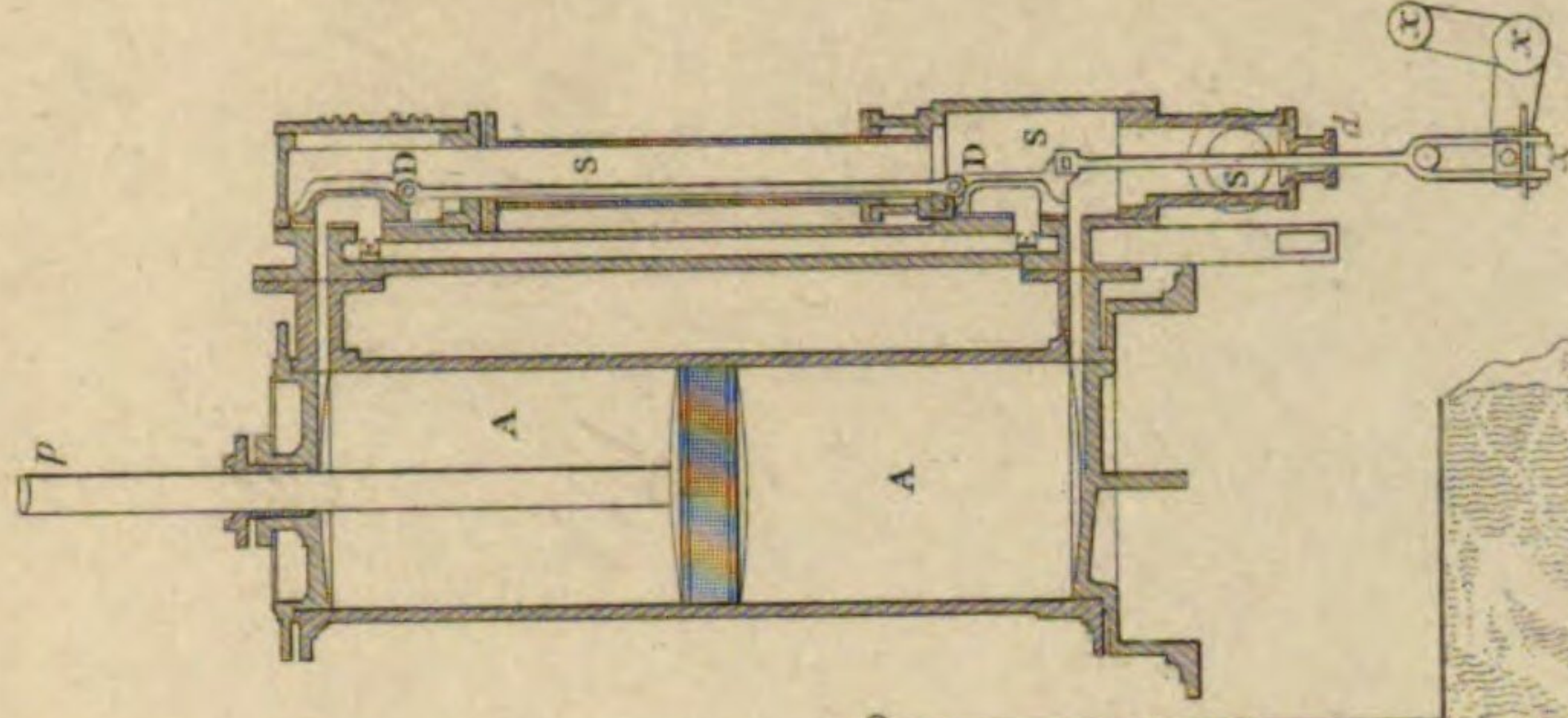
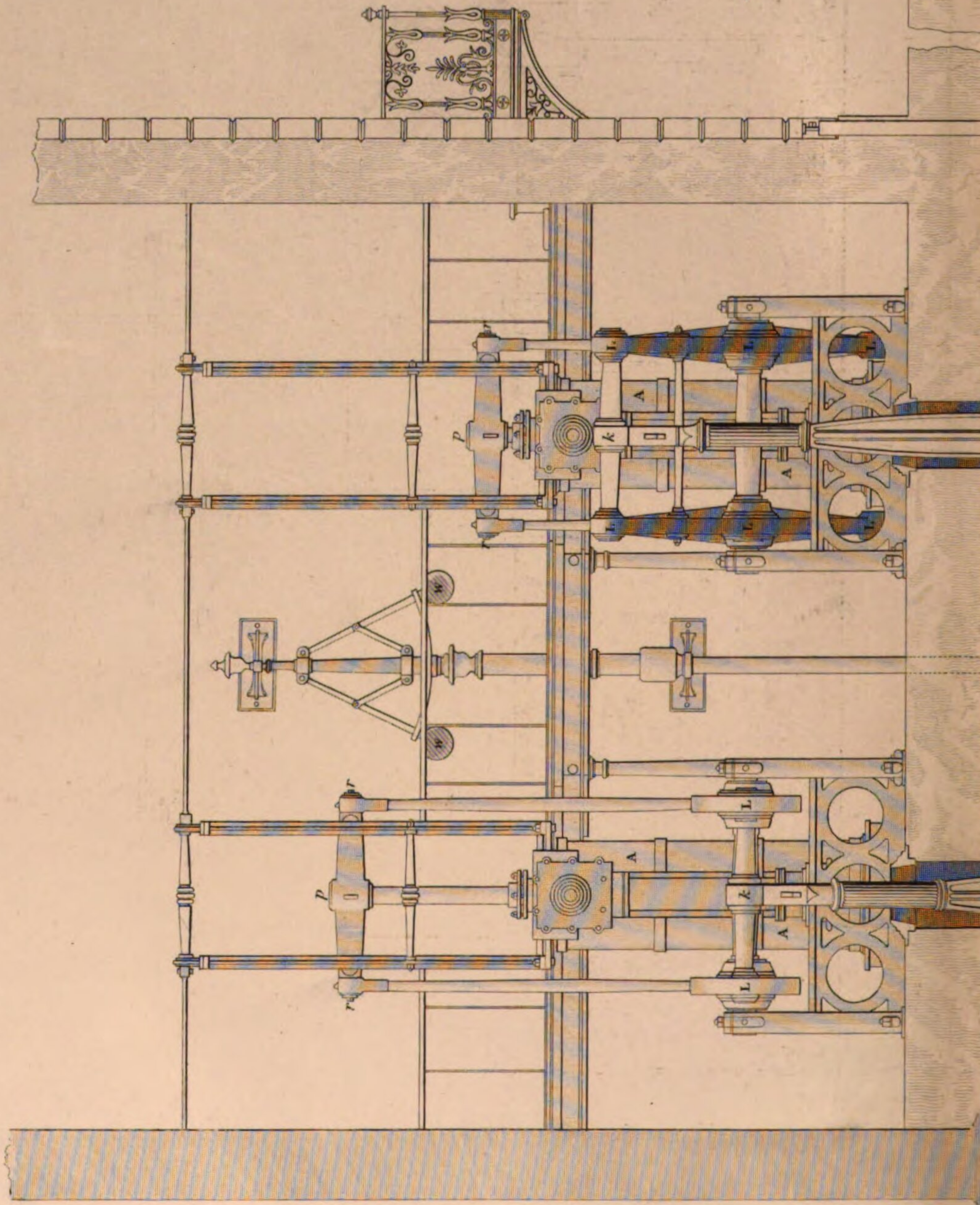


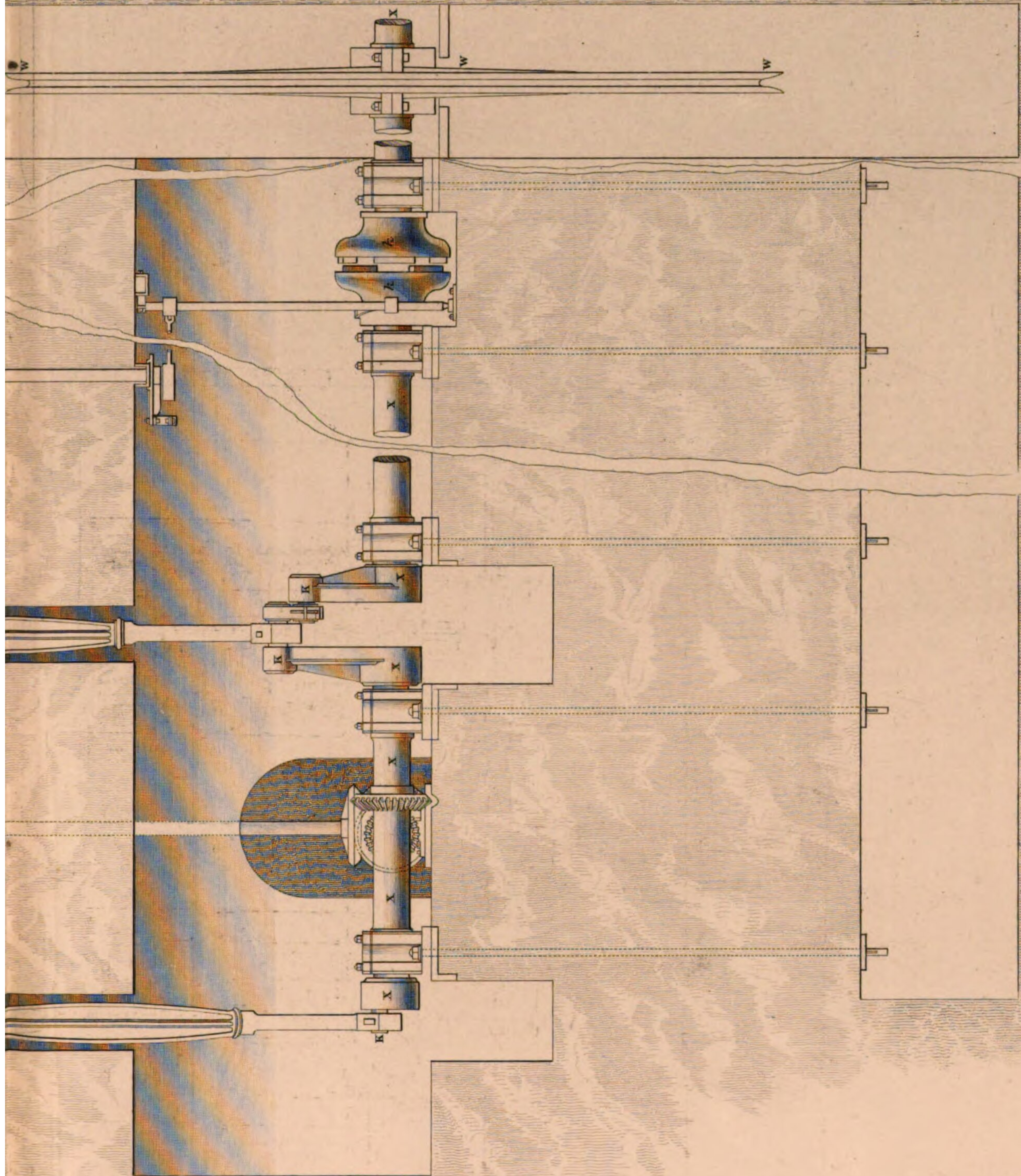
Fig. 2.



High Pressure Engine used at the Liverpool Railway Station.

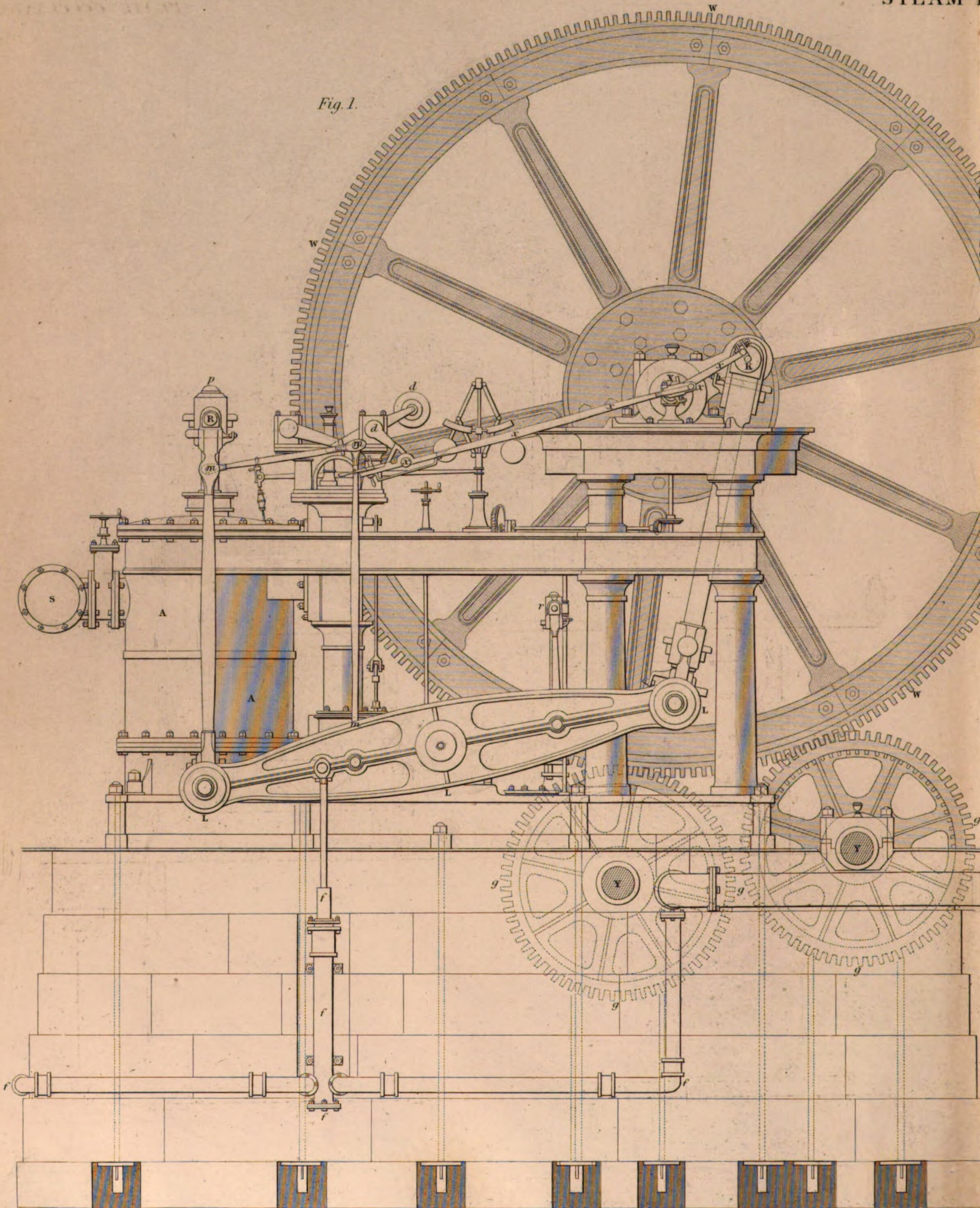


Sectional End Elevation.

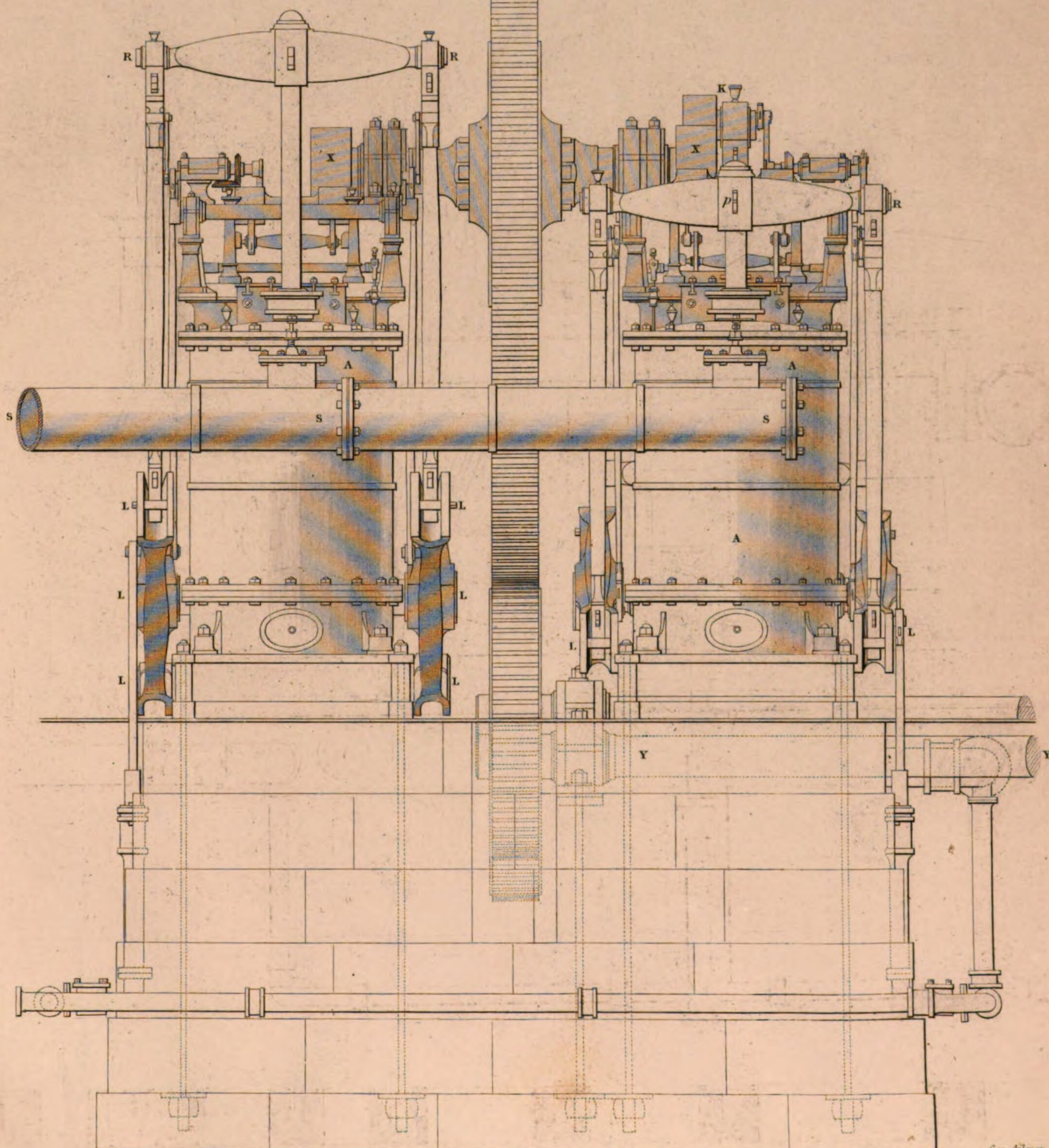


Geo. Aikman, Sculp^r

Fig. 1.



This image shows a vertical strip of a manuscript page, possibly a flyleaf or endpaper. It features a repeating pattern of horizontal lines, with a central vertical line running through the middle. The paper is heavily stained and discolored, with a prominent blue and yellow stain near the top. The strip is narrow and appears to be a fragment of a larger page.



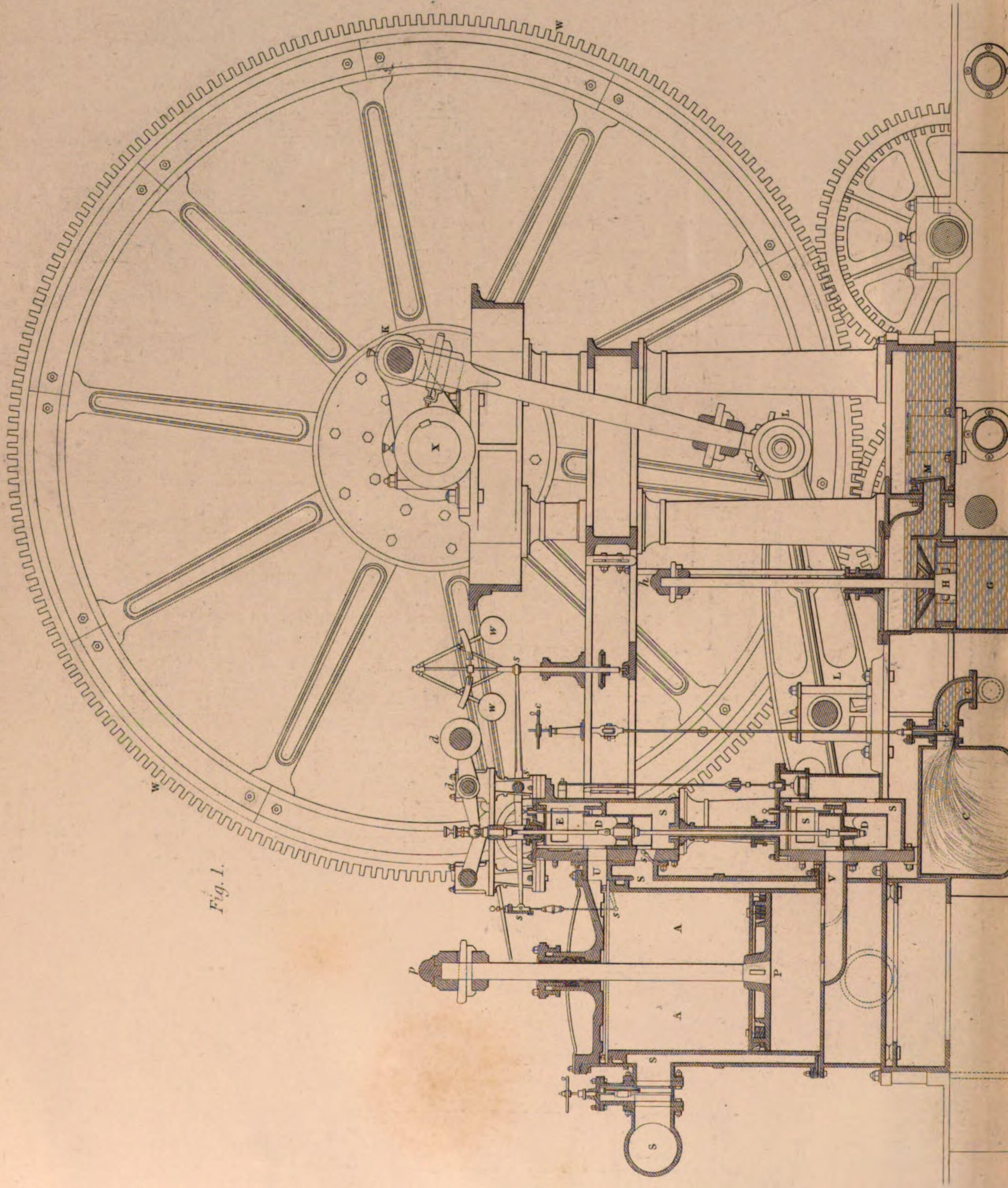


Fig. 1.

Longitudinal Section.

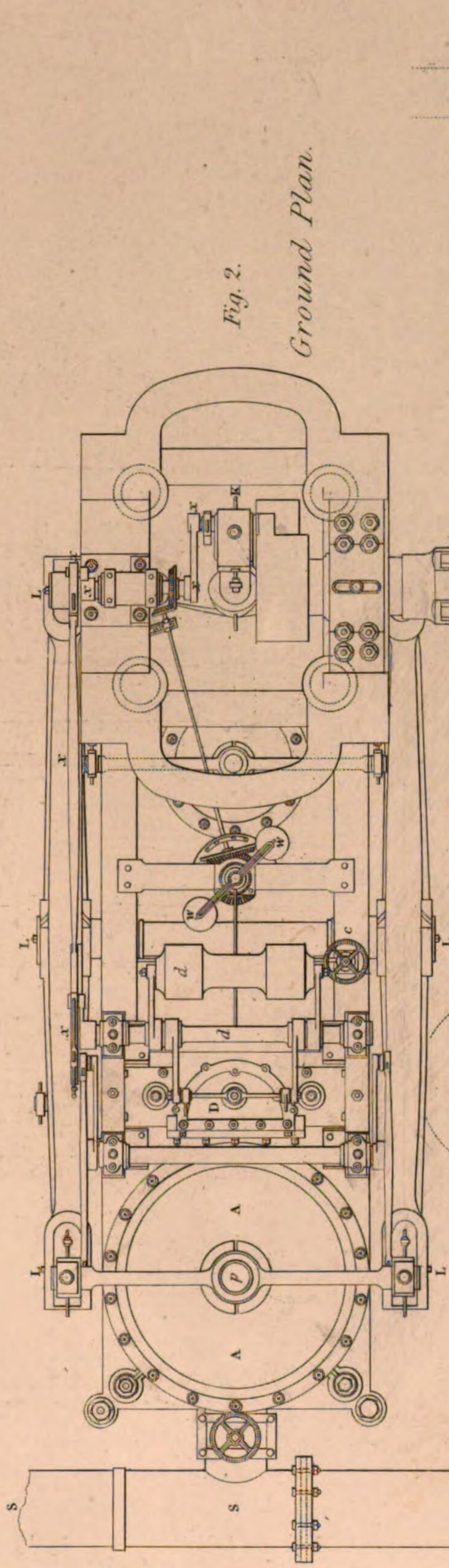
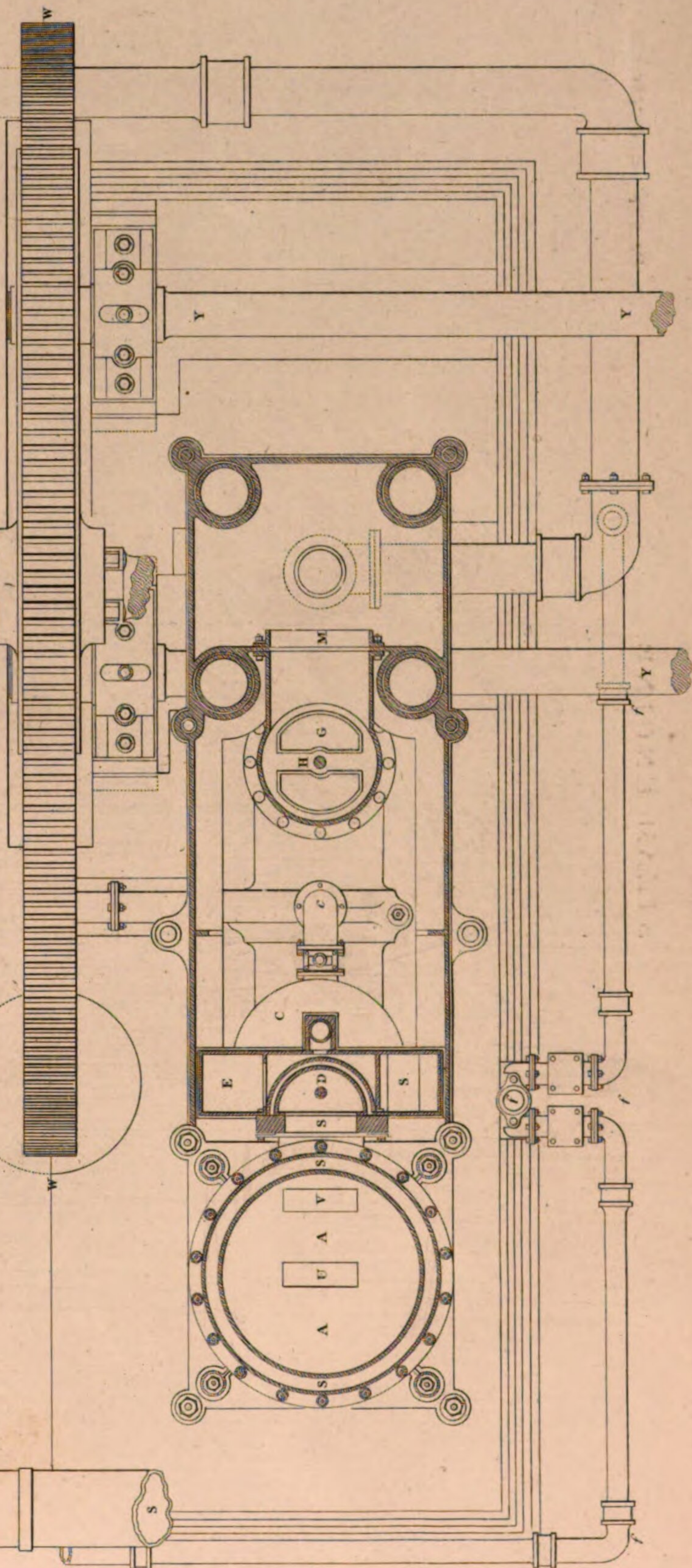
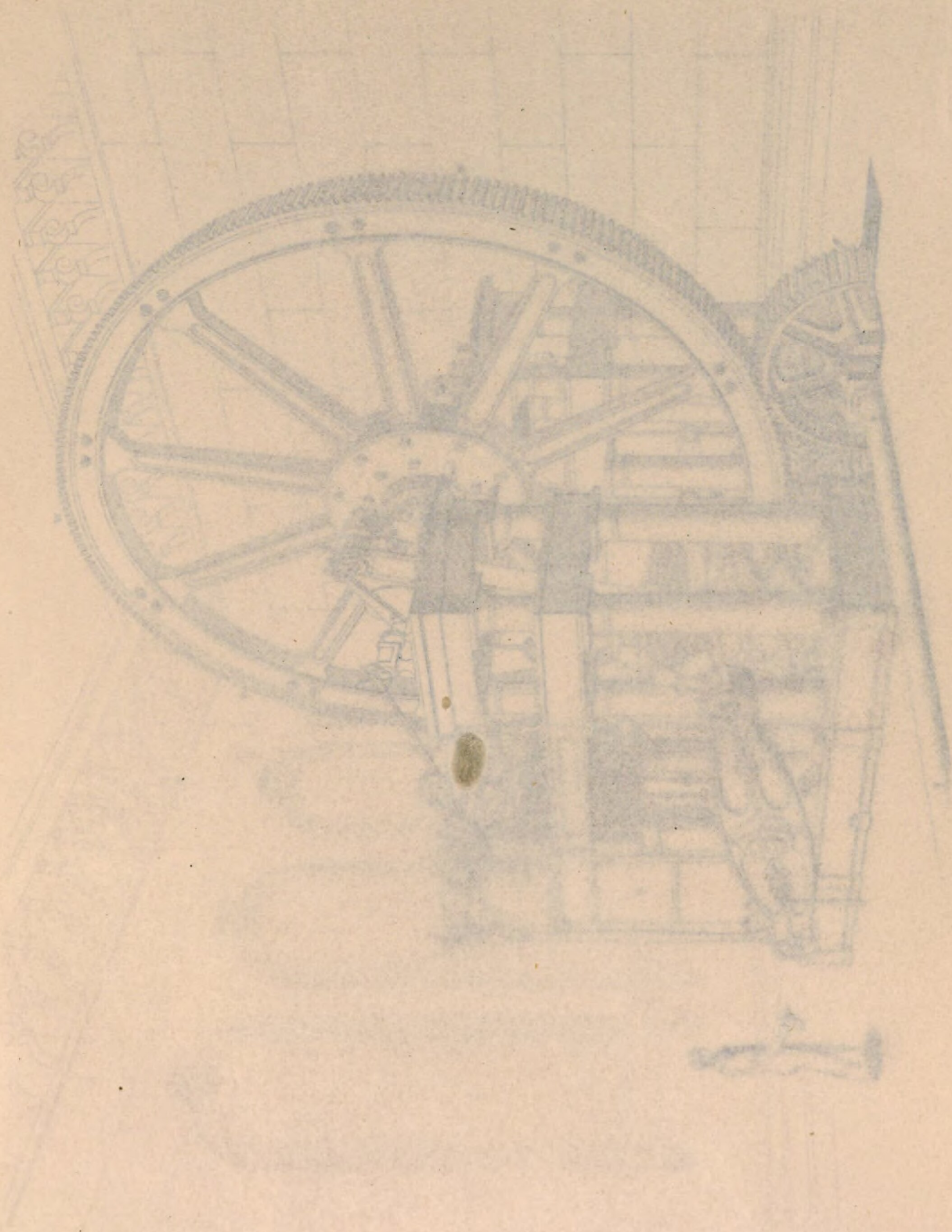
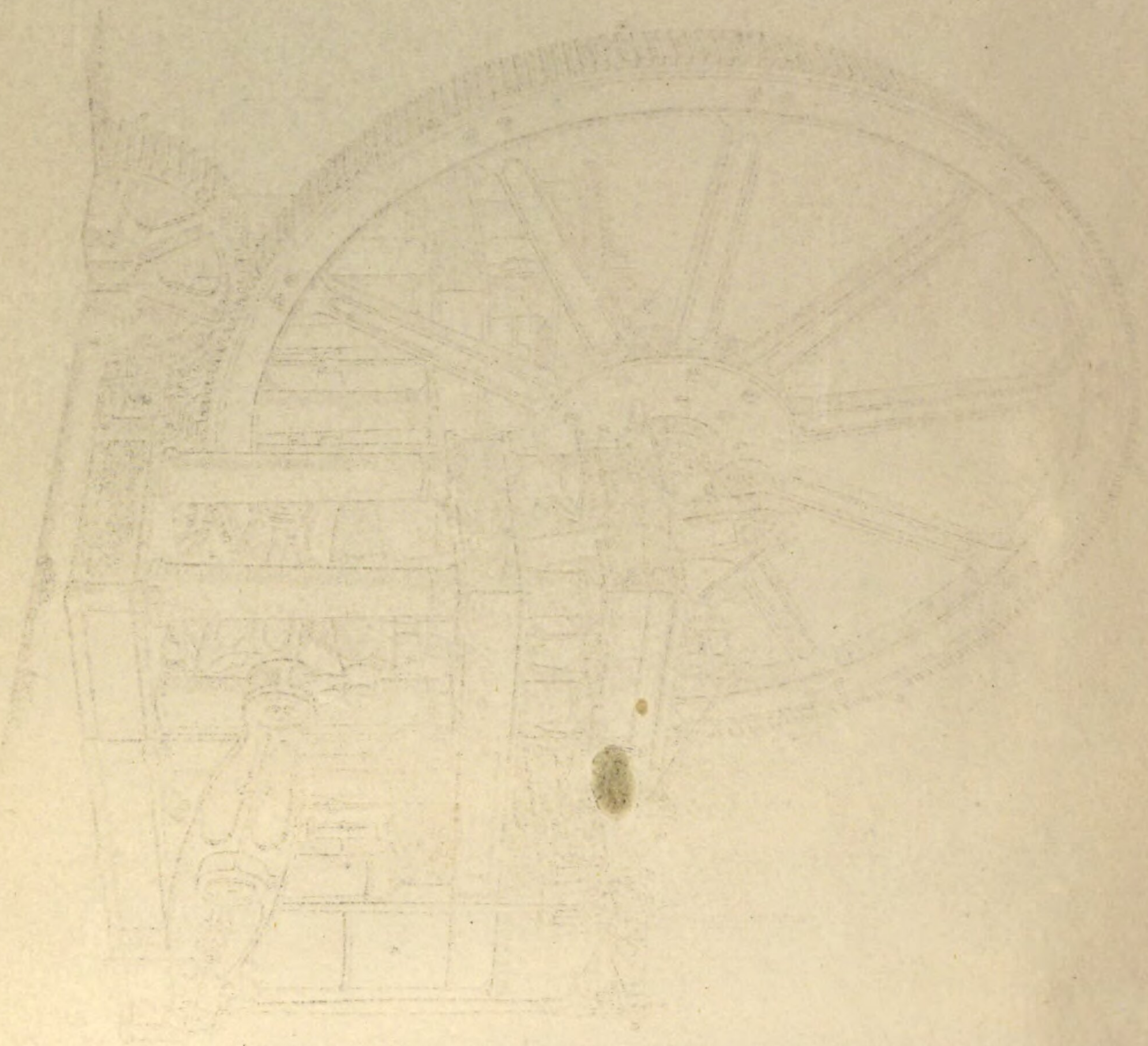


Fig. 2.
Ground Plan.



Sectional Ground Plan.





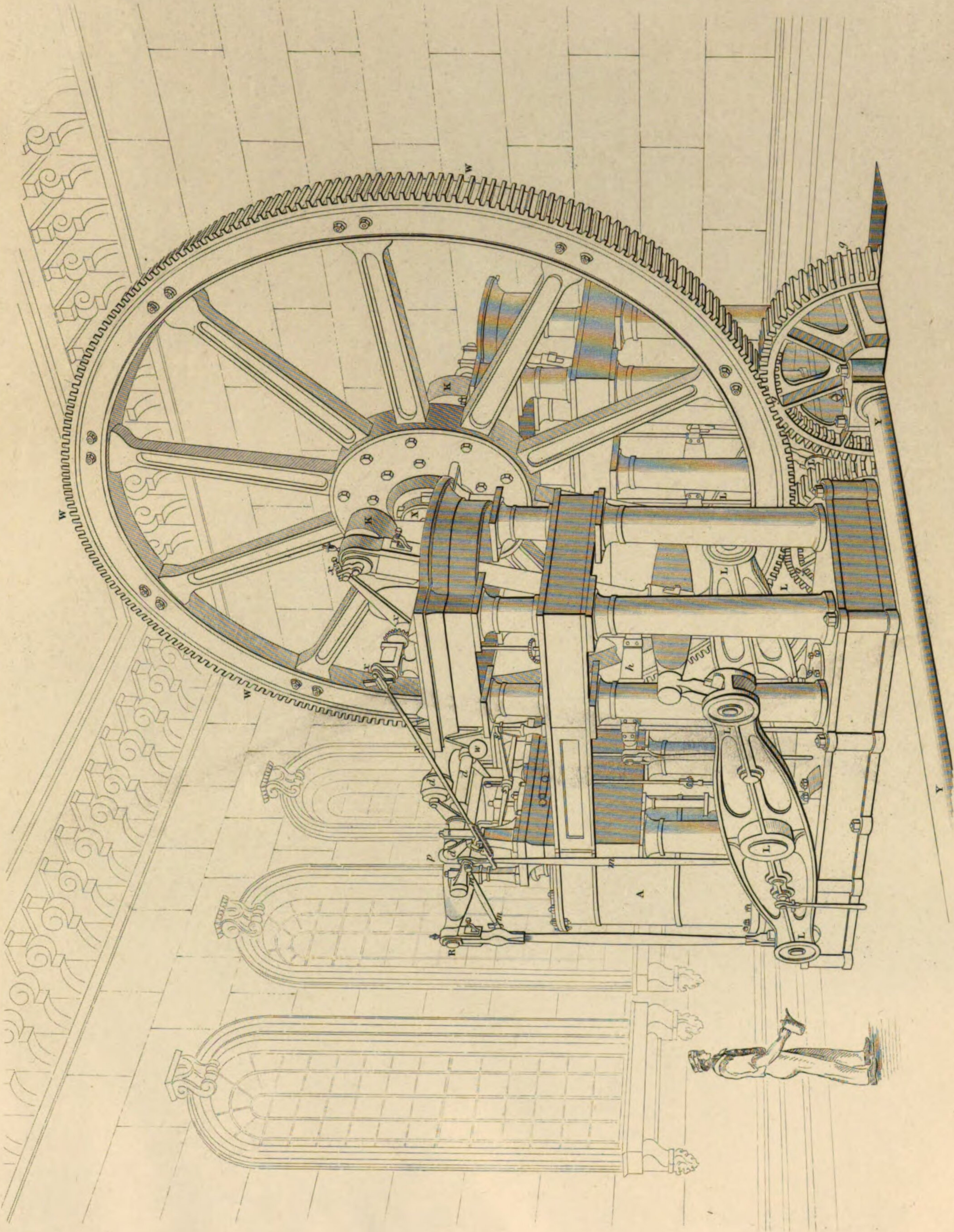


Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

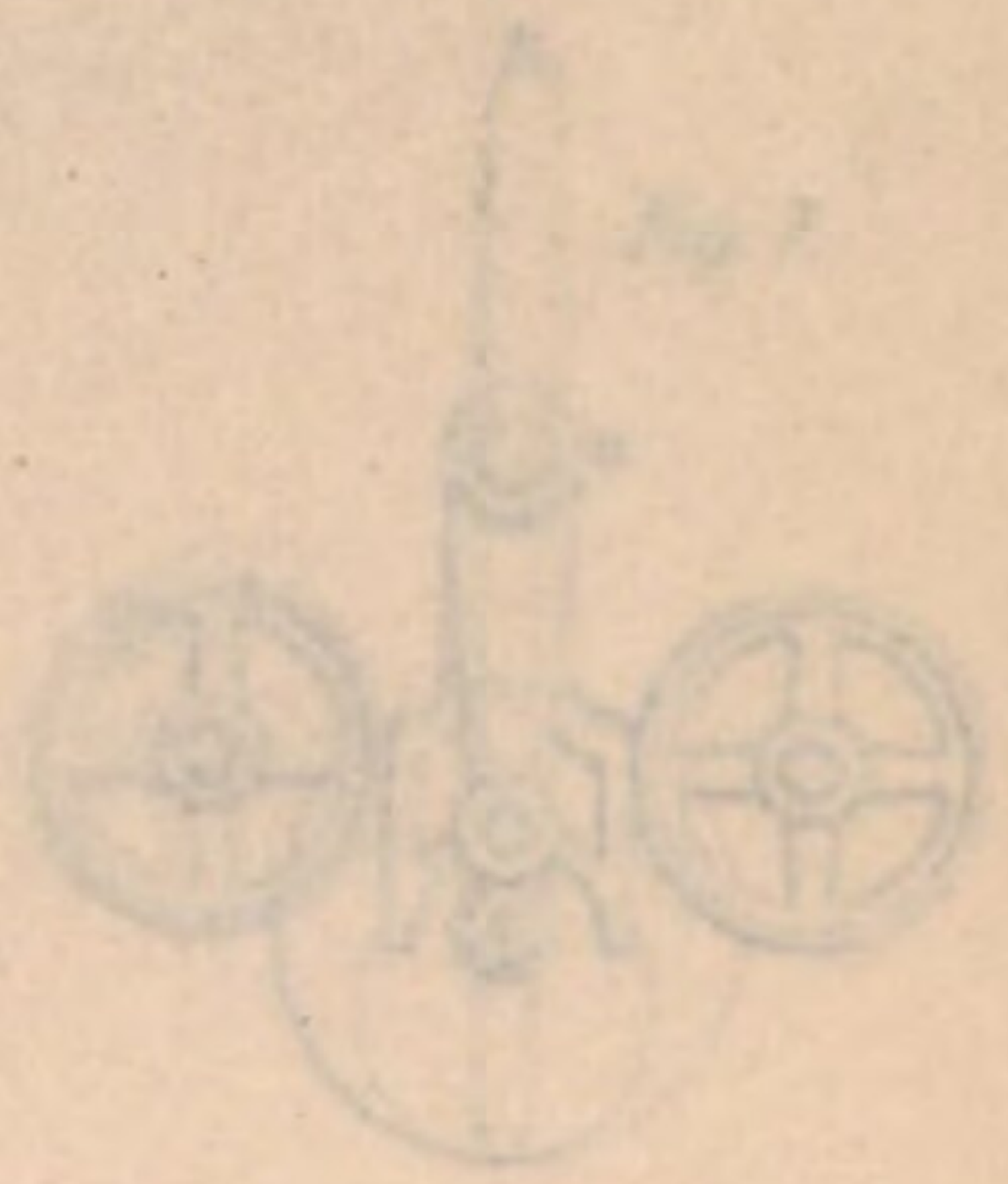
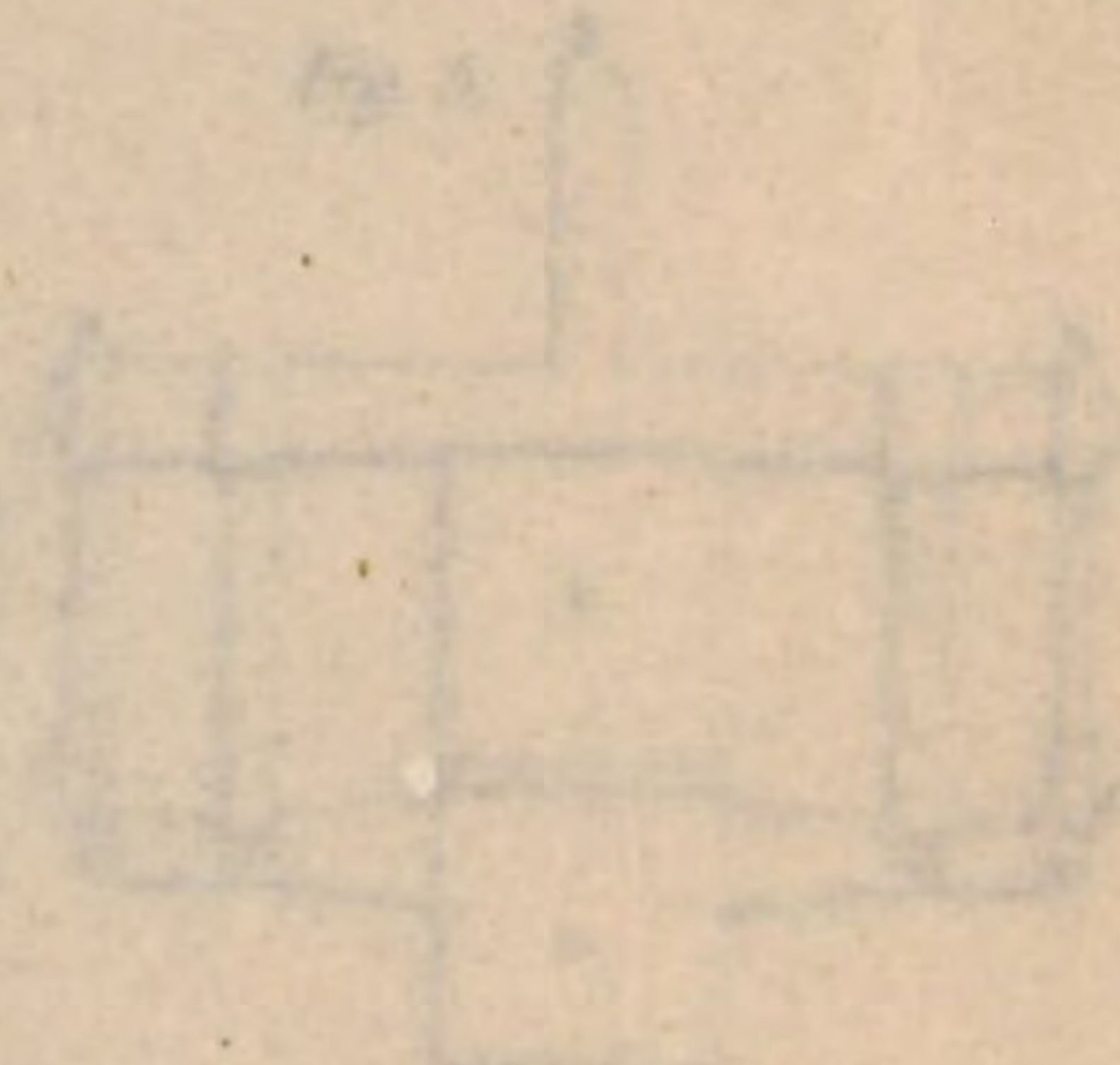
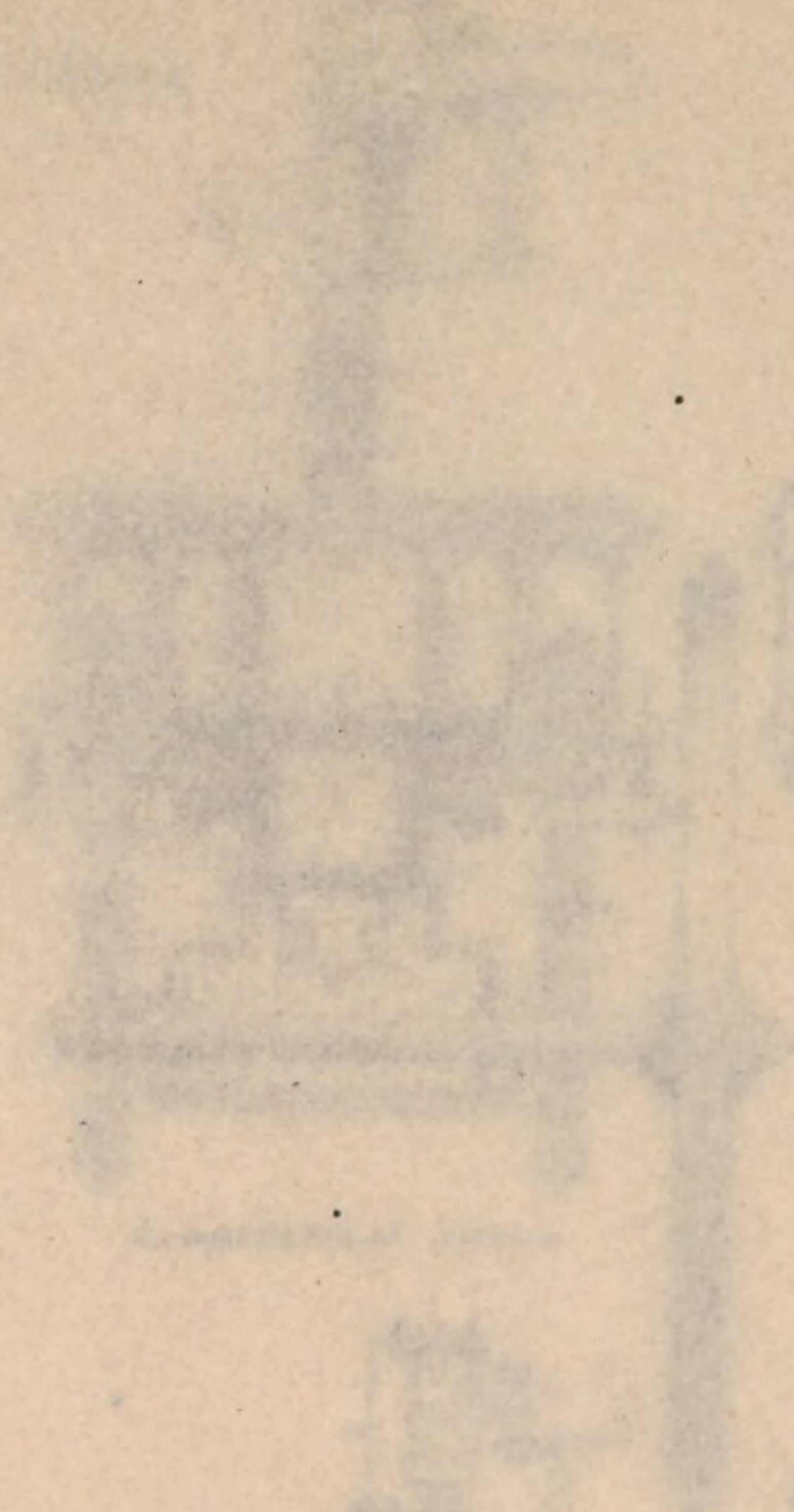
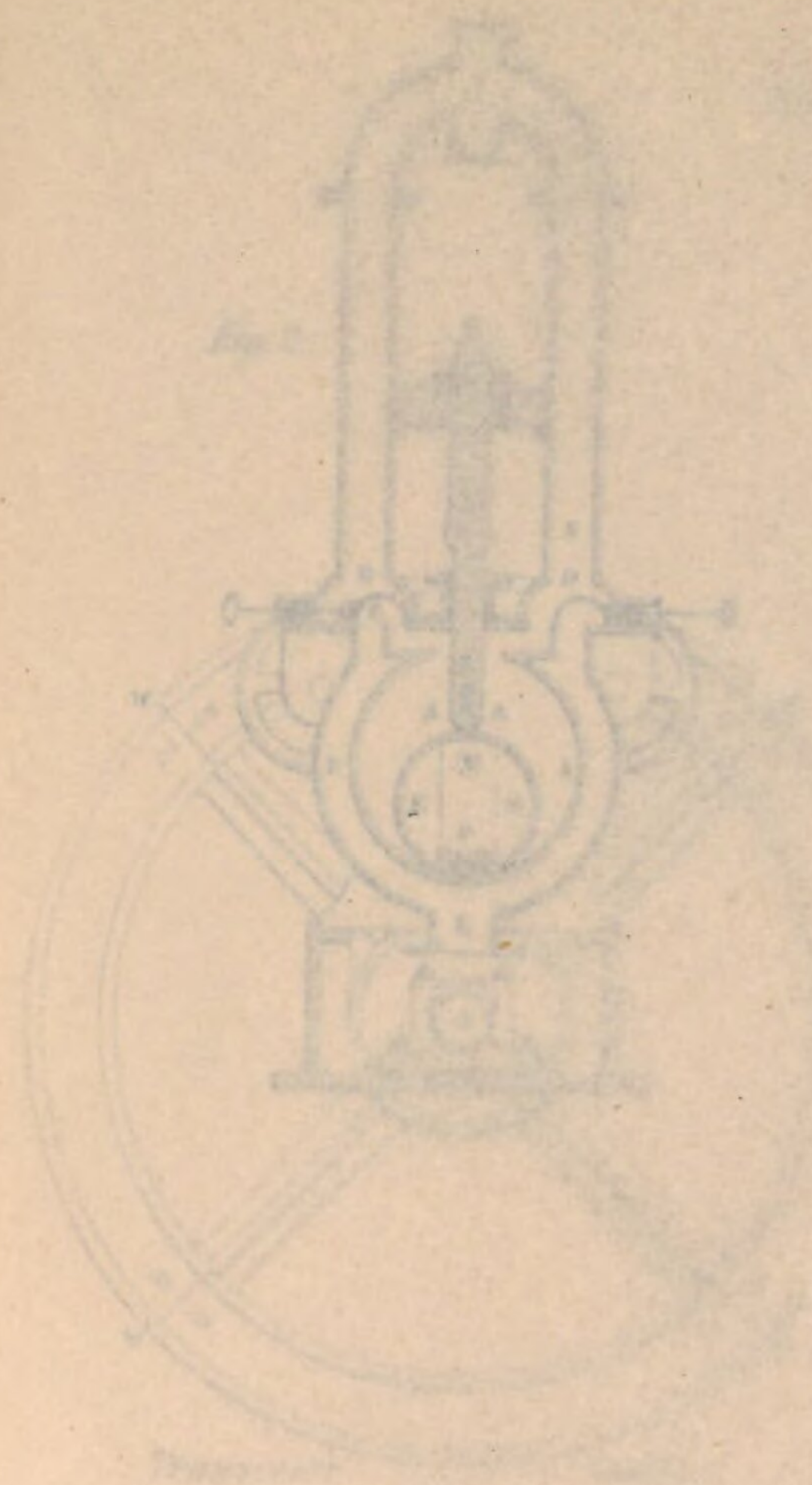


Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

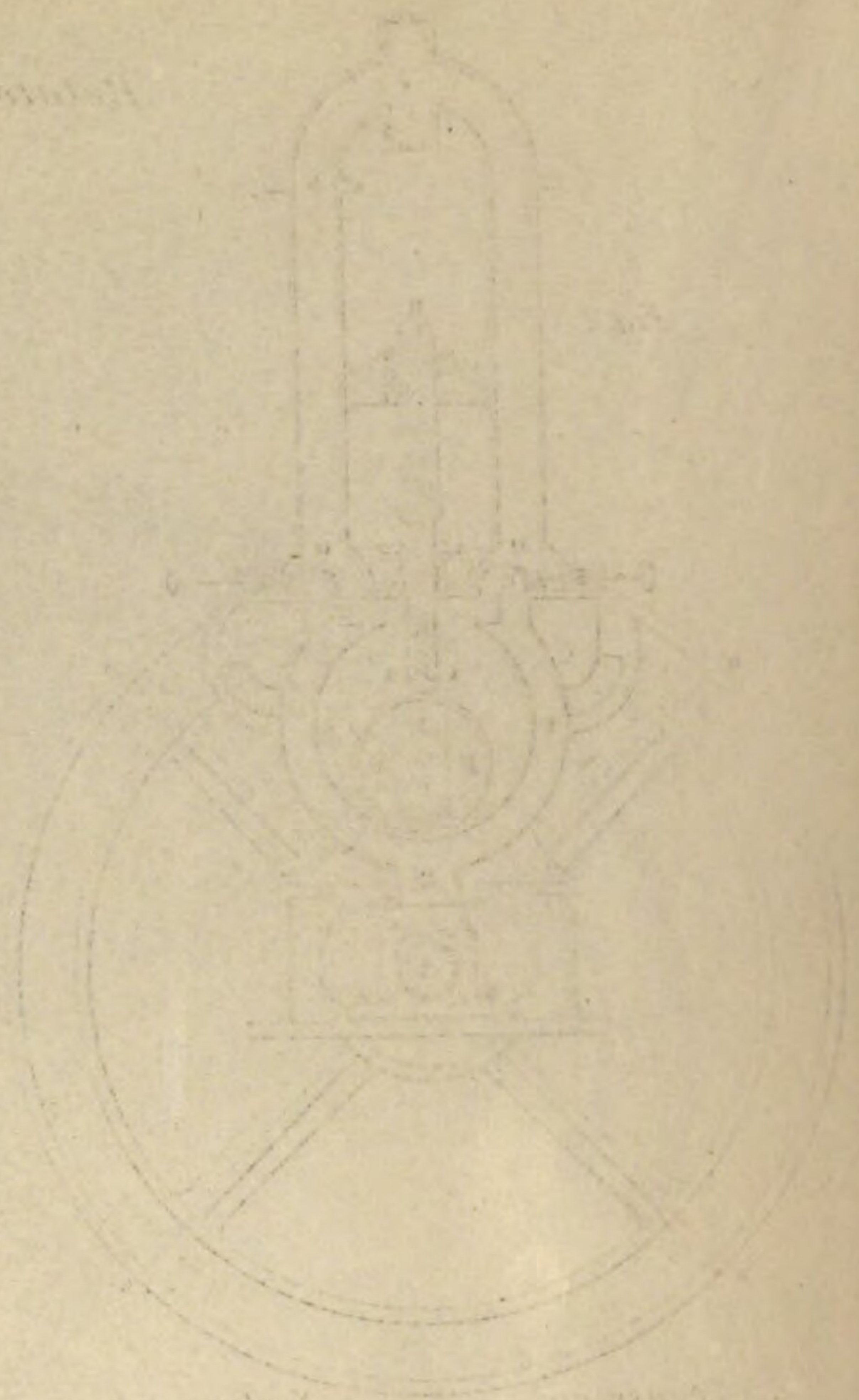


Fig. 1



Fig. 2

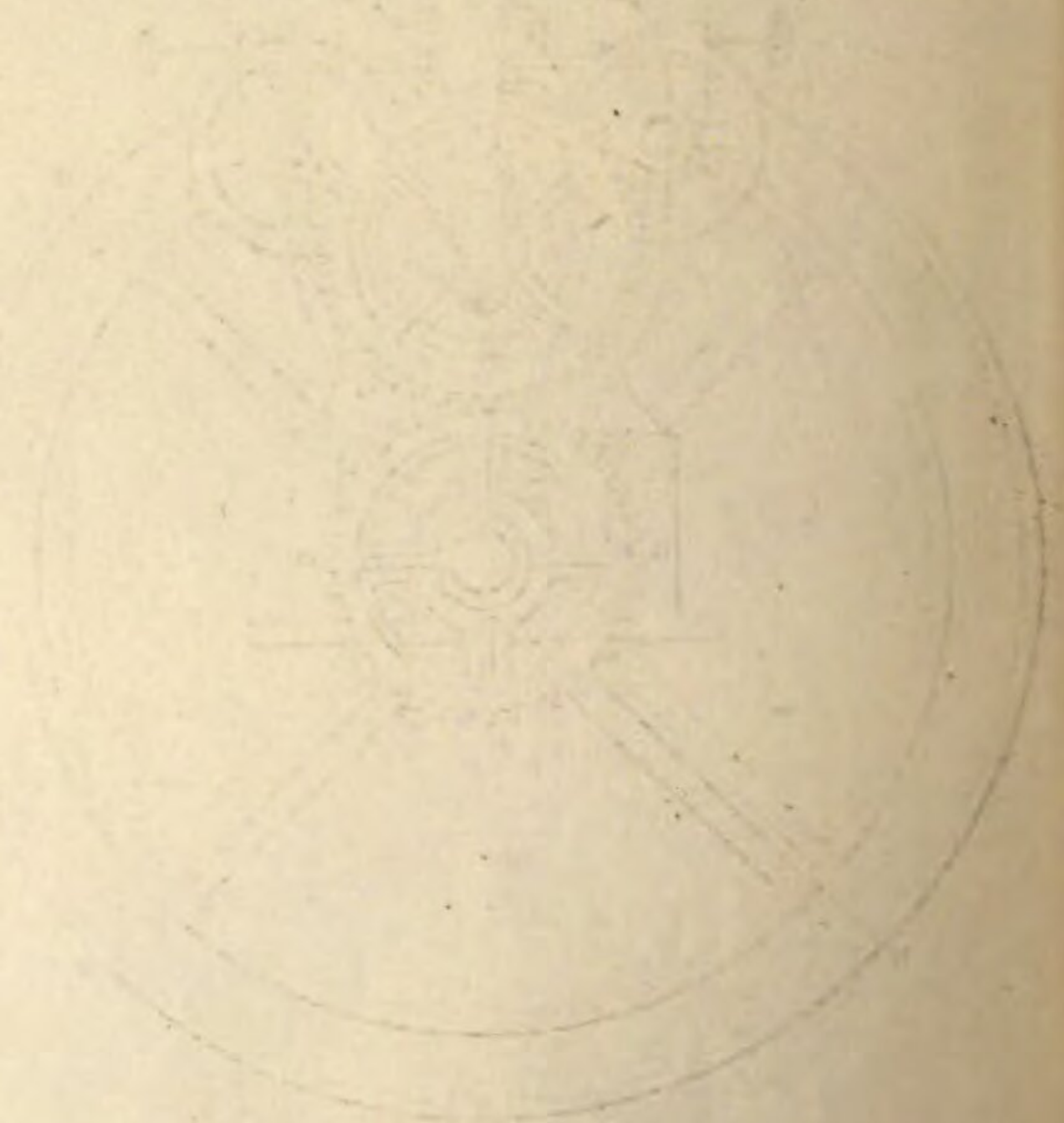


Fig. 3

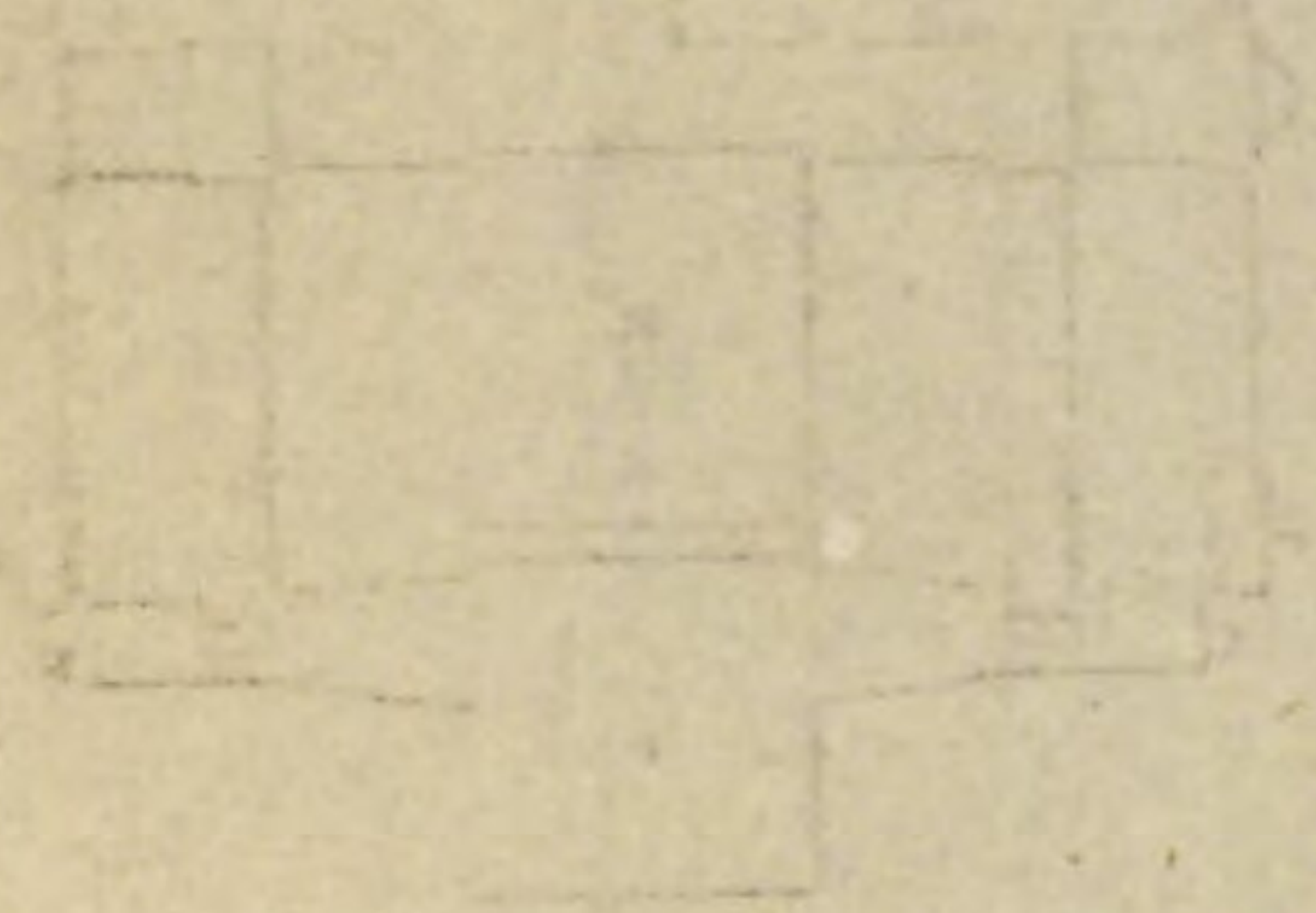


Fig. 4

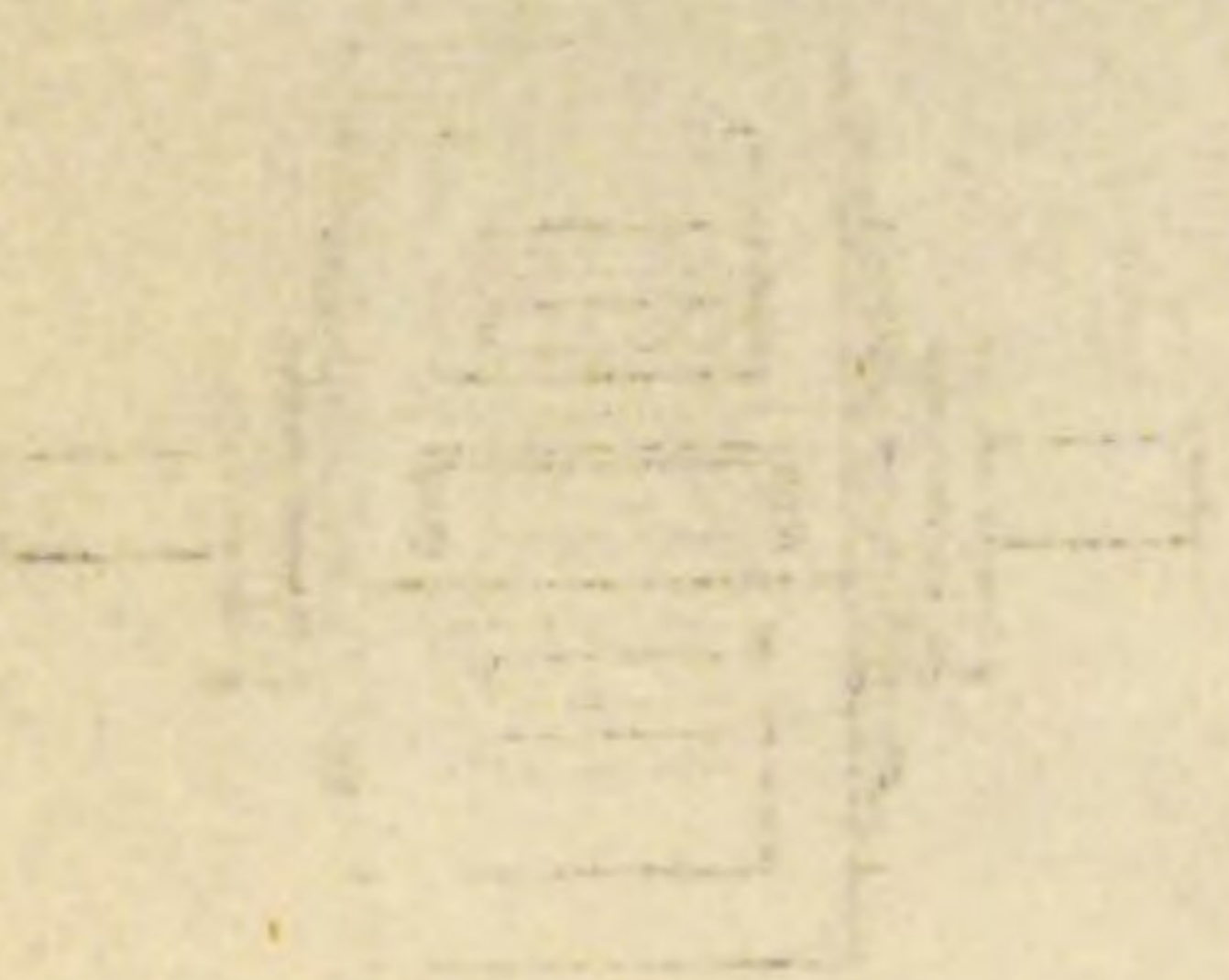


Fig. 5



Fig. 6



Fig. 7



Fig. 8

Rotatory Engine.

Fig. 2.

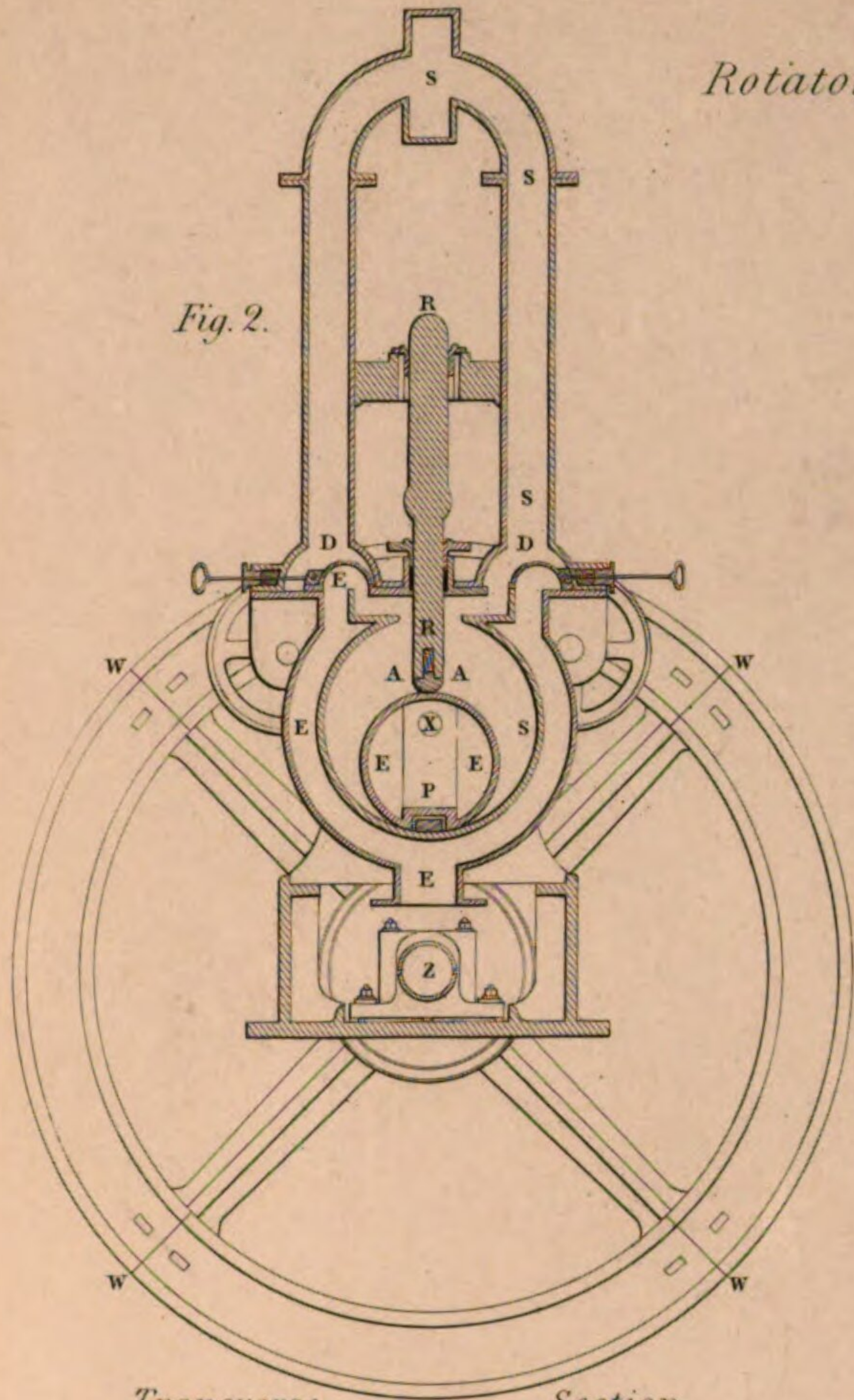


Fig. 1.

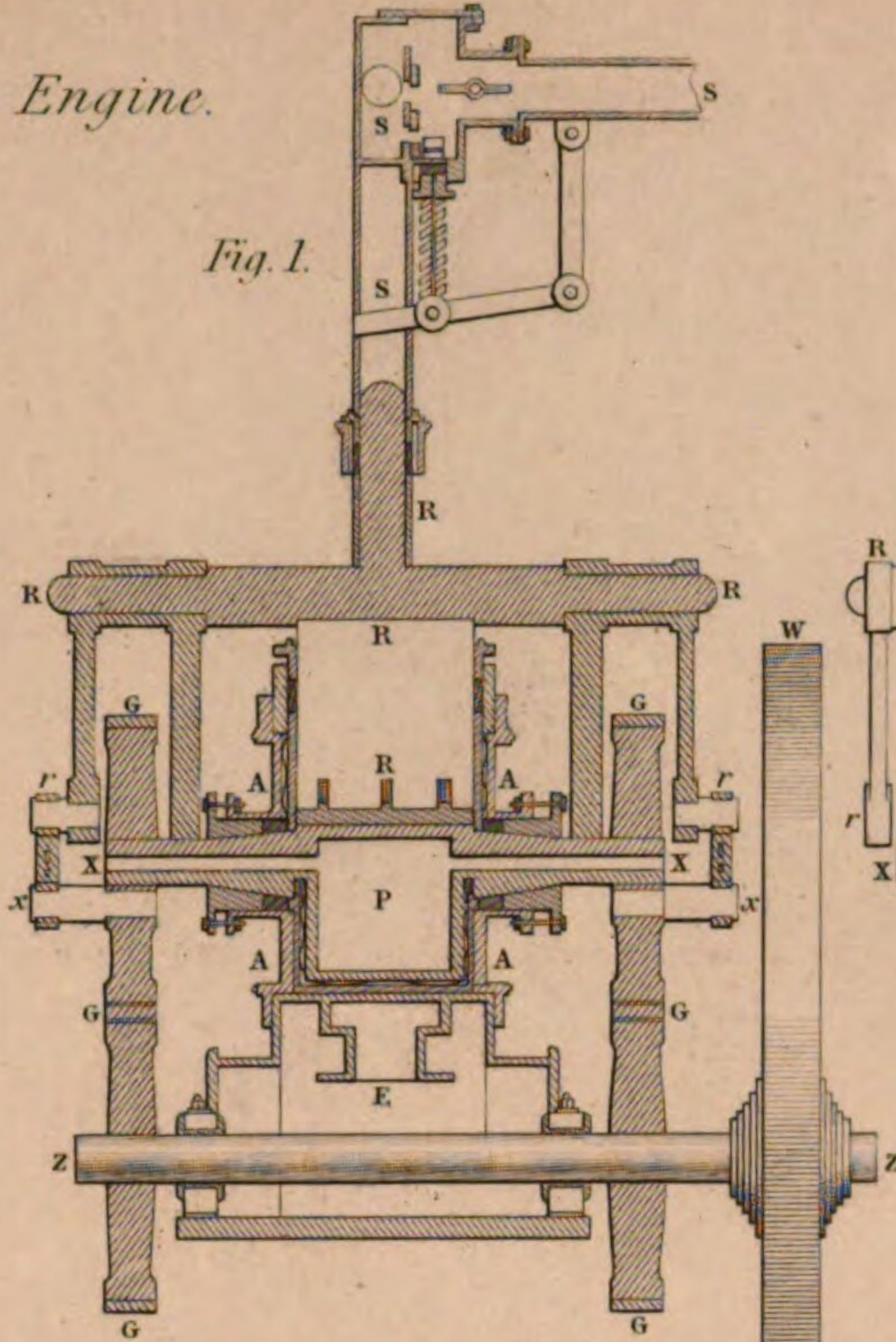


Fig. 5.

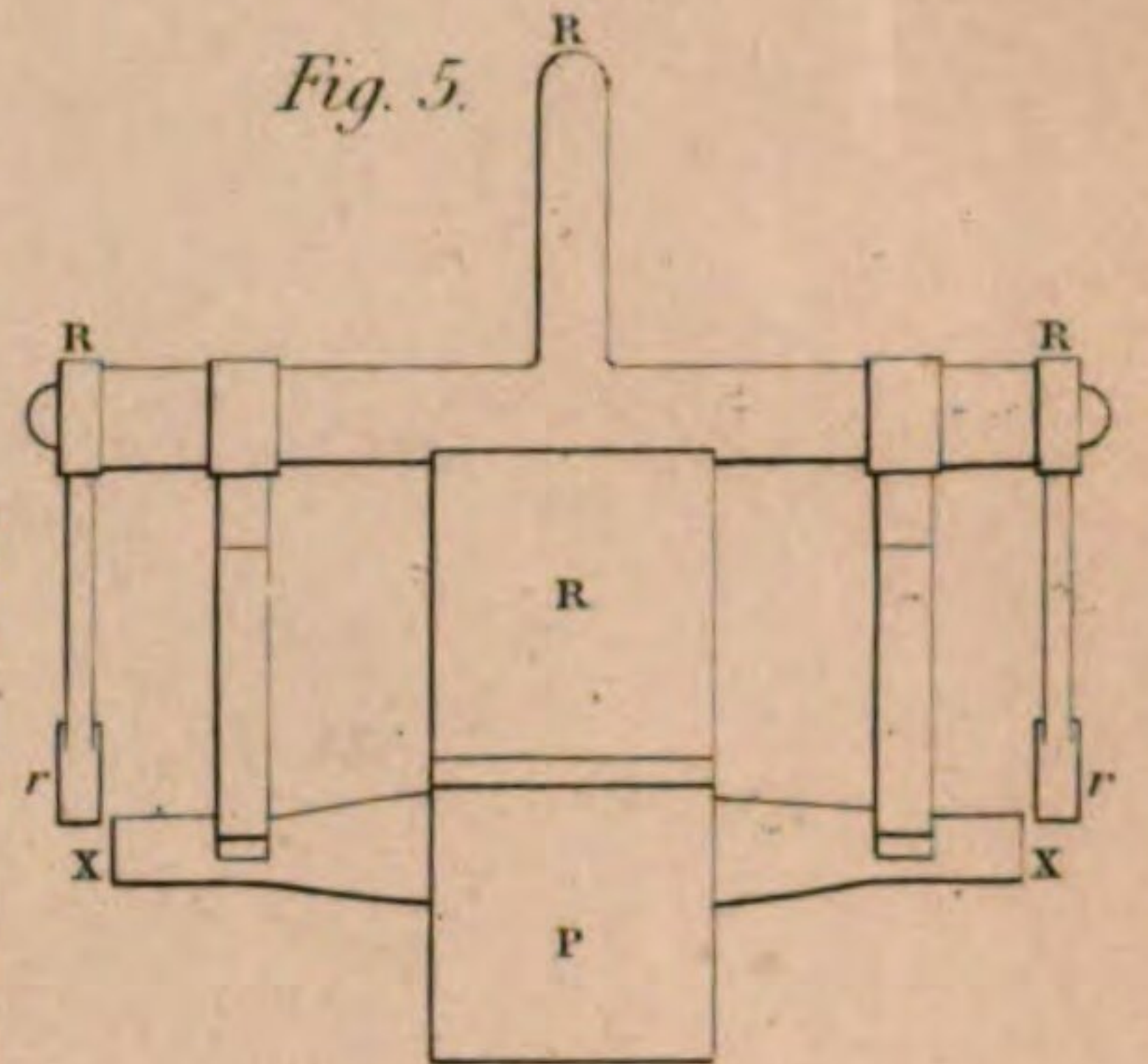


Fig. 6.

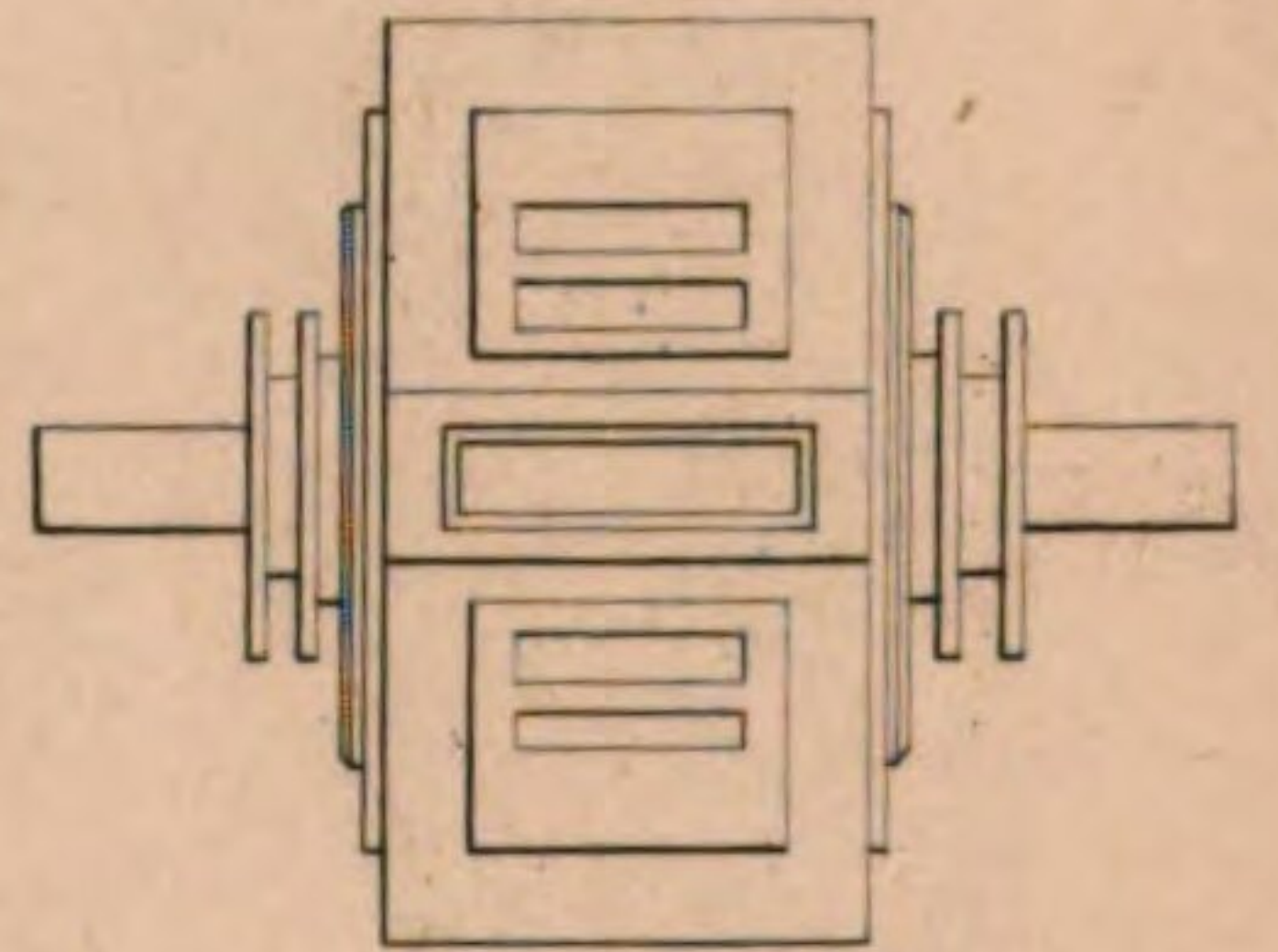


Fig. 4.

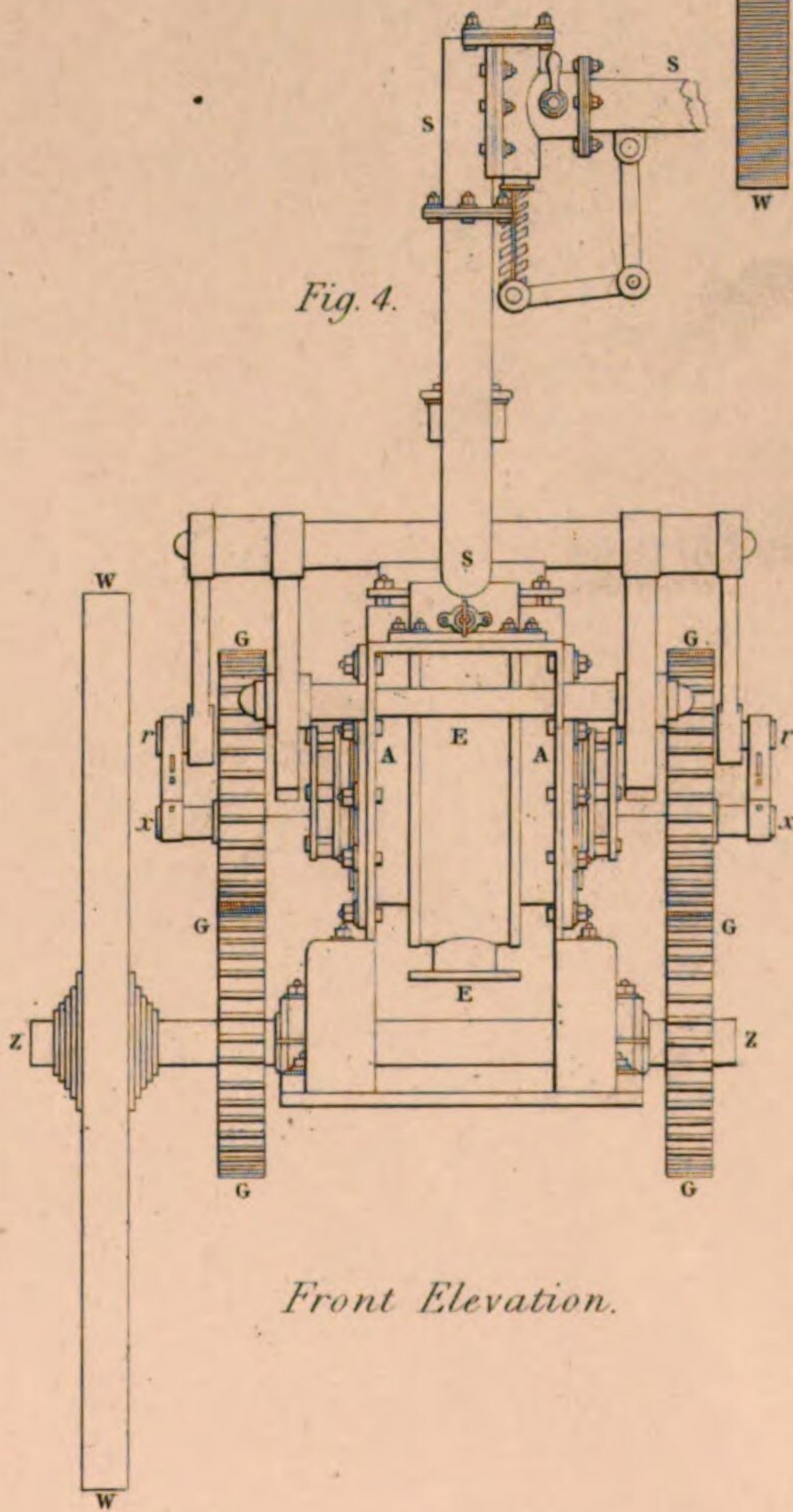


Fig. 7.

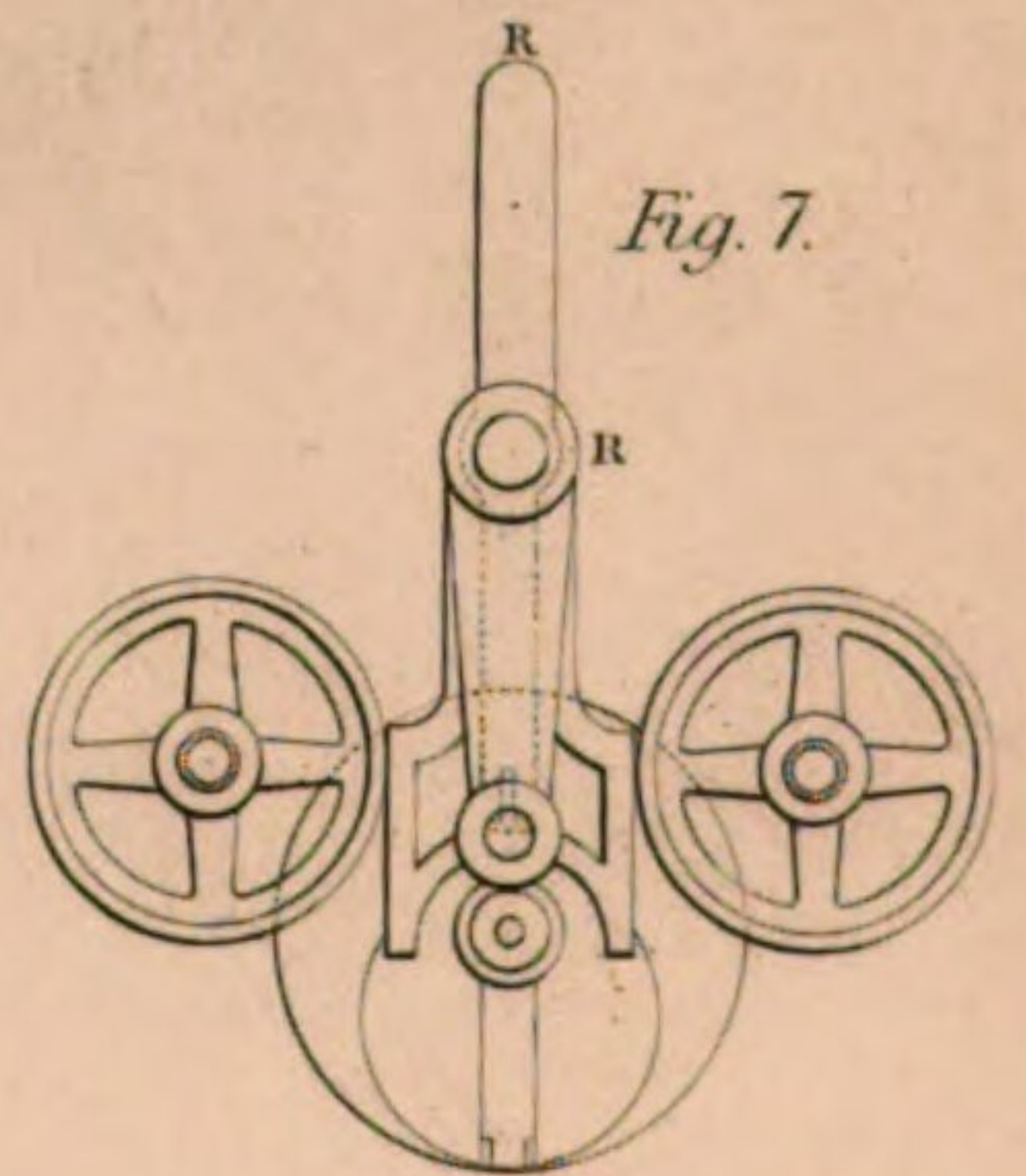


Fig. 8.

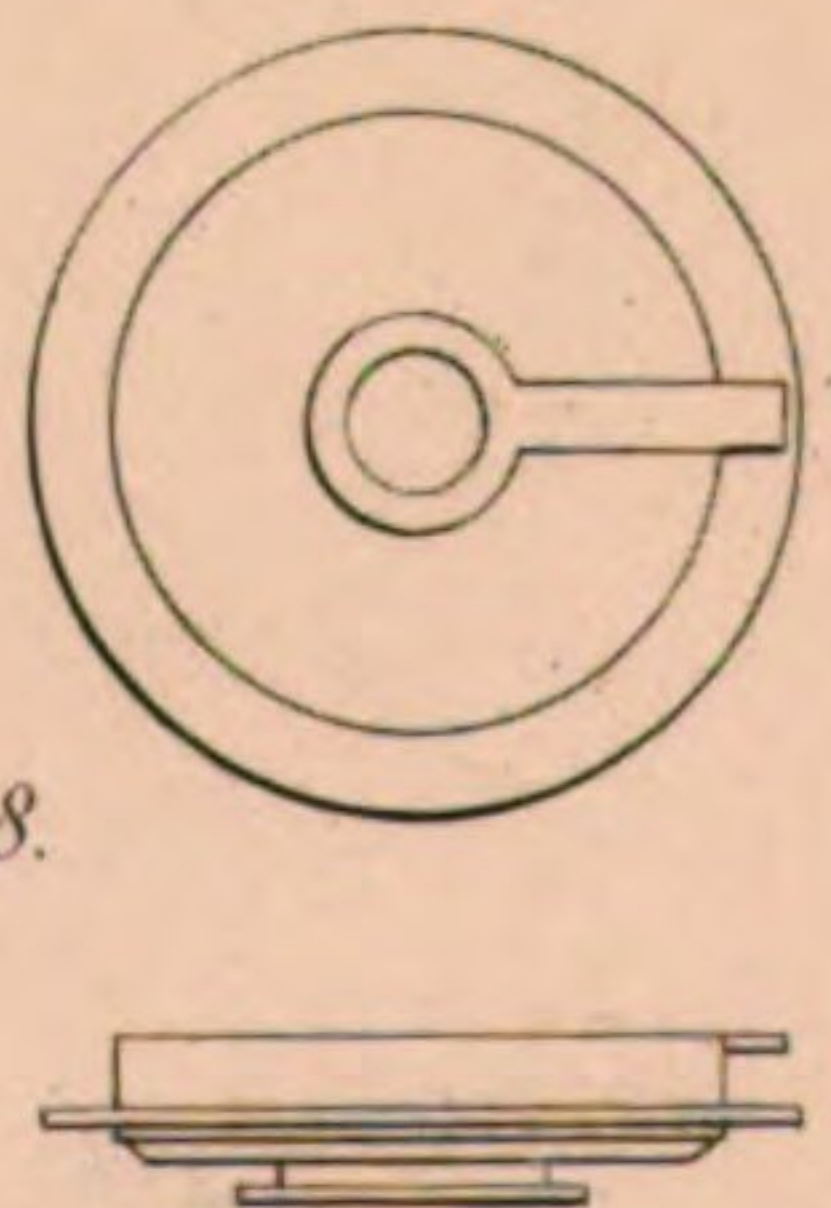
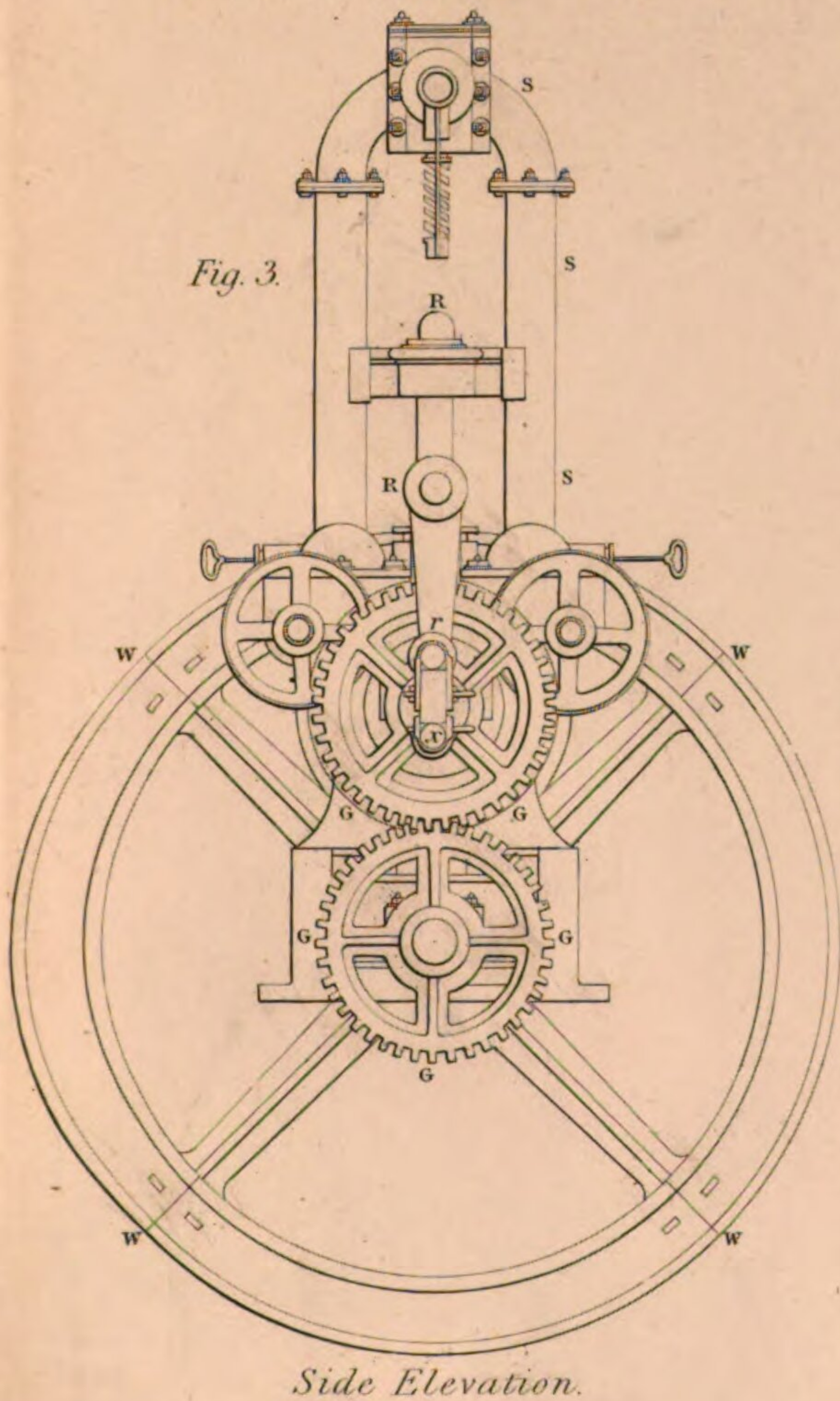
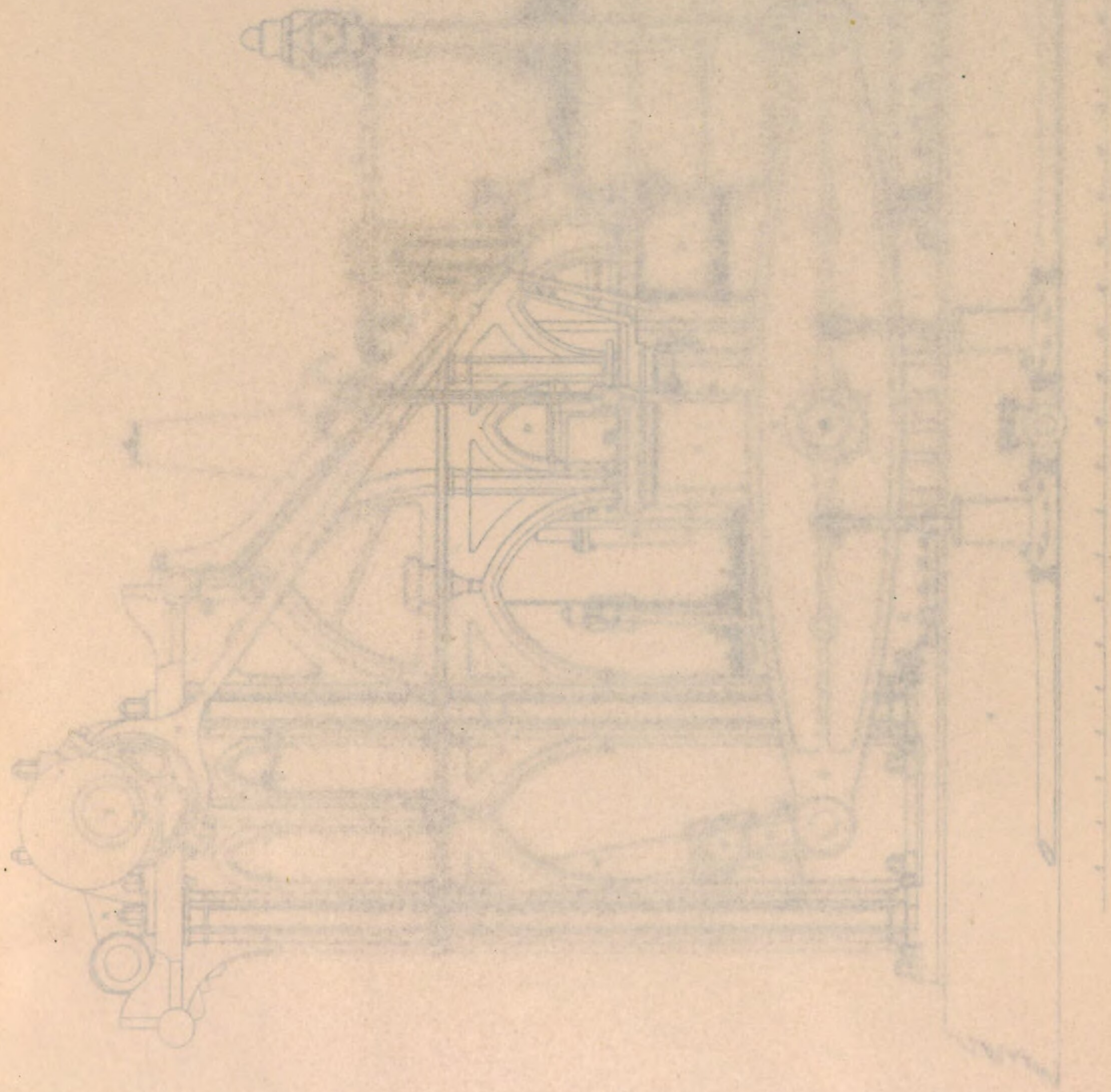
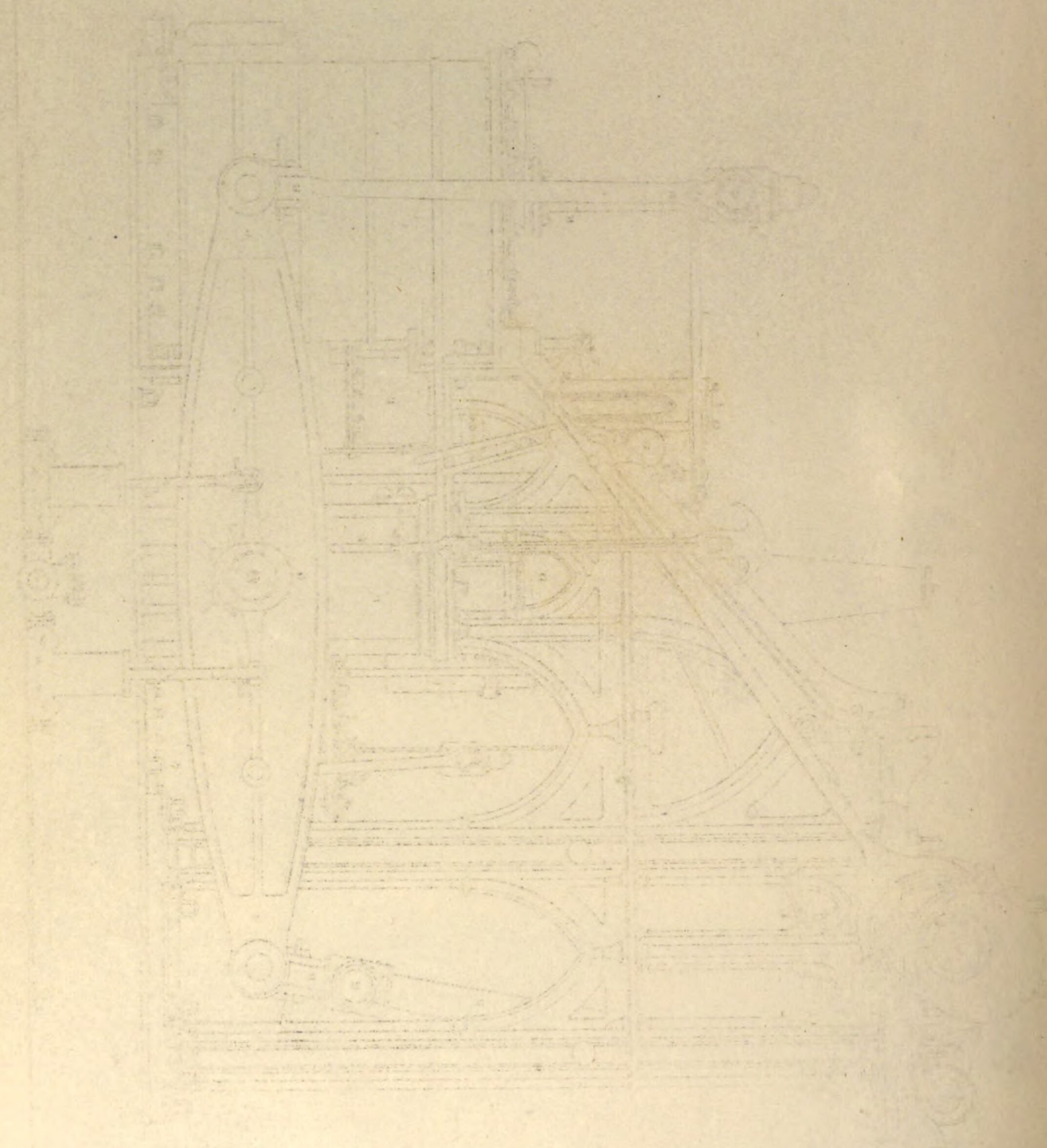
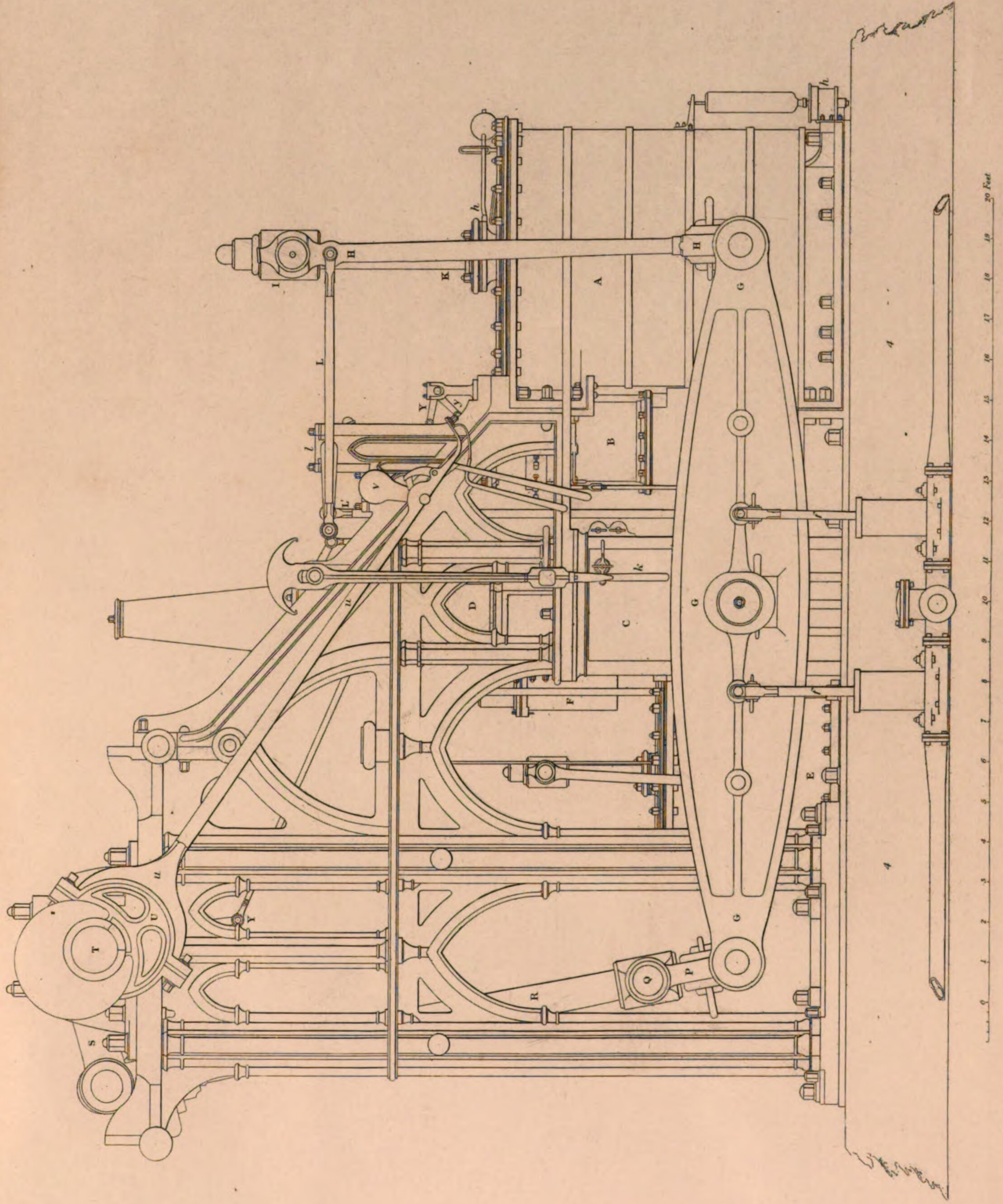


Fig. 3.



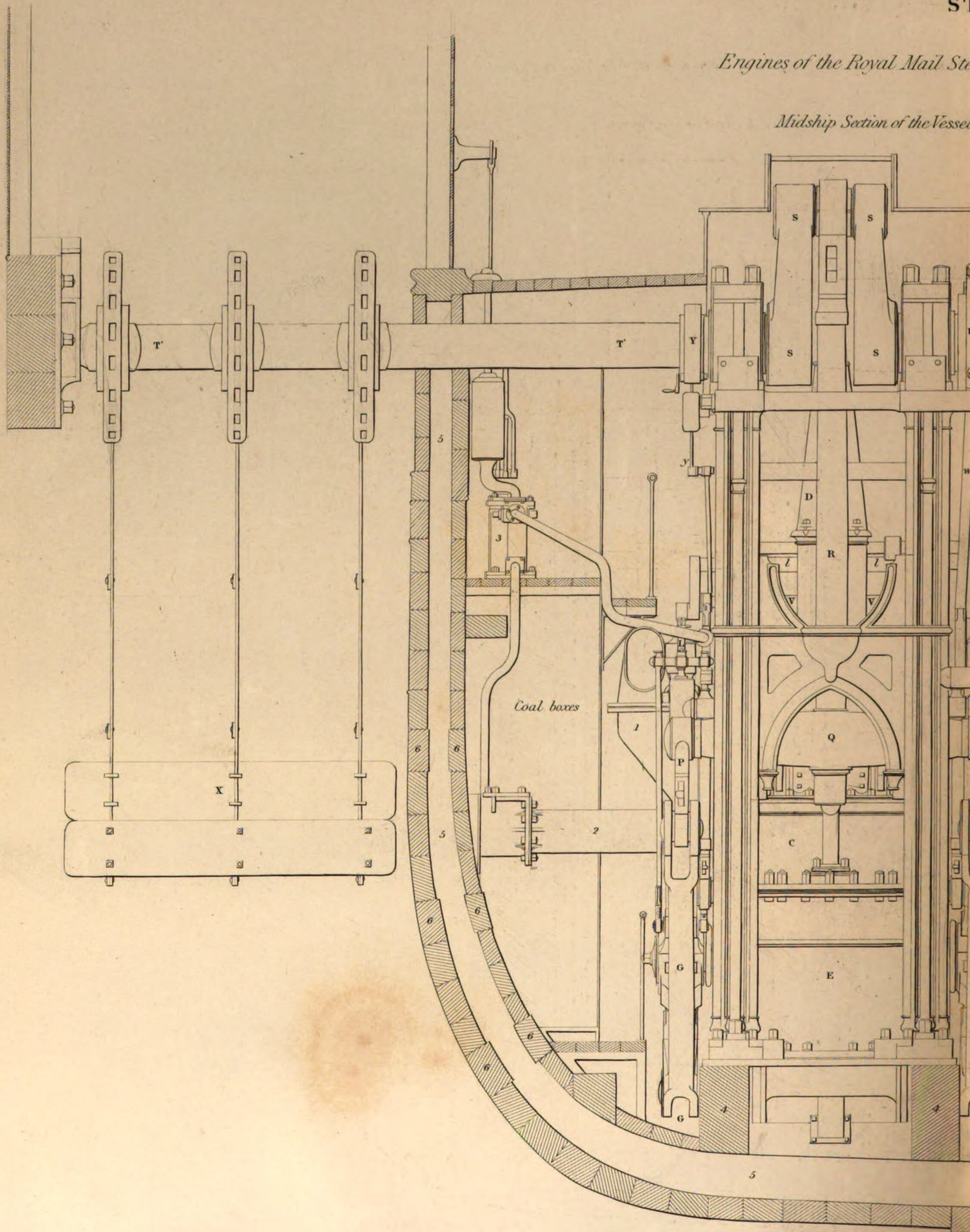






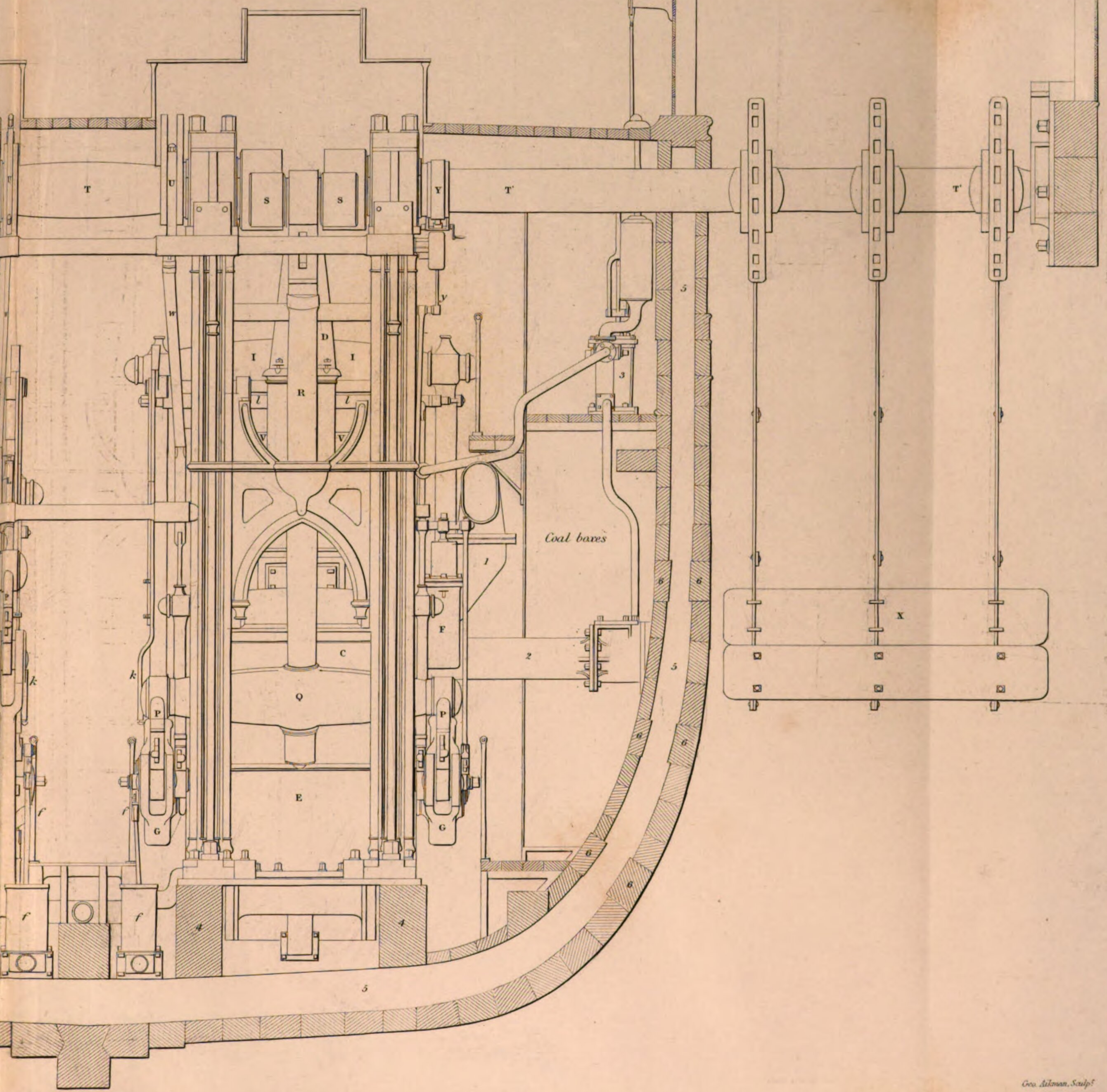
Engines of the Royal Mail Steamer

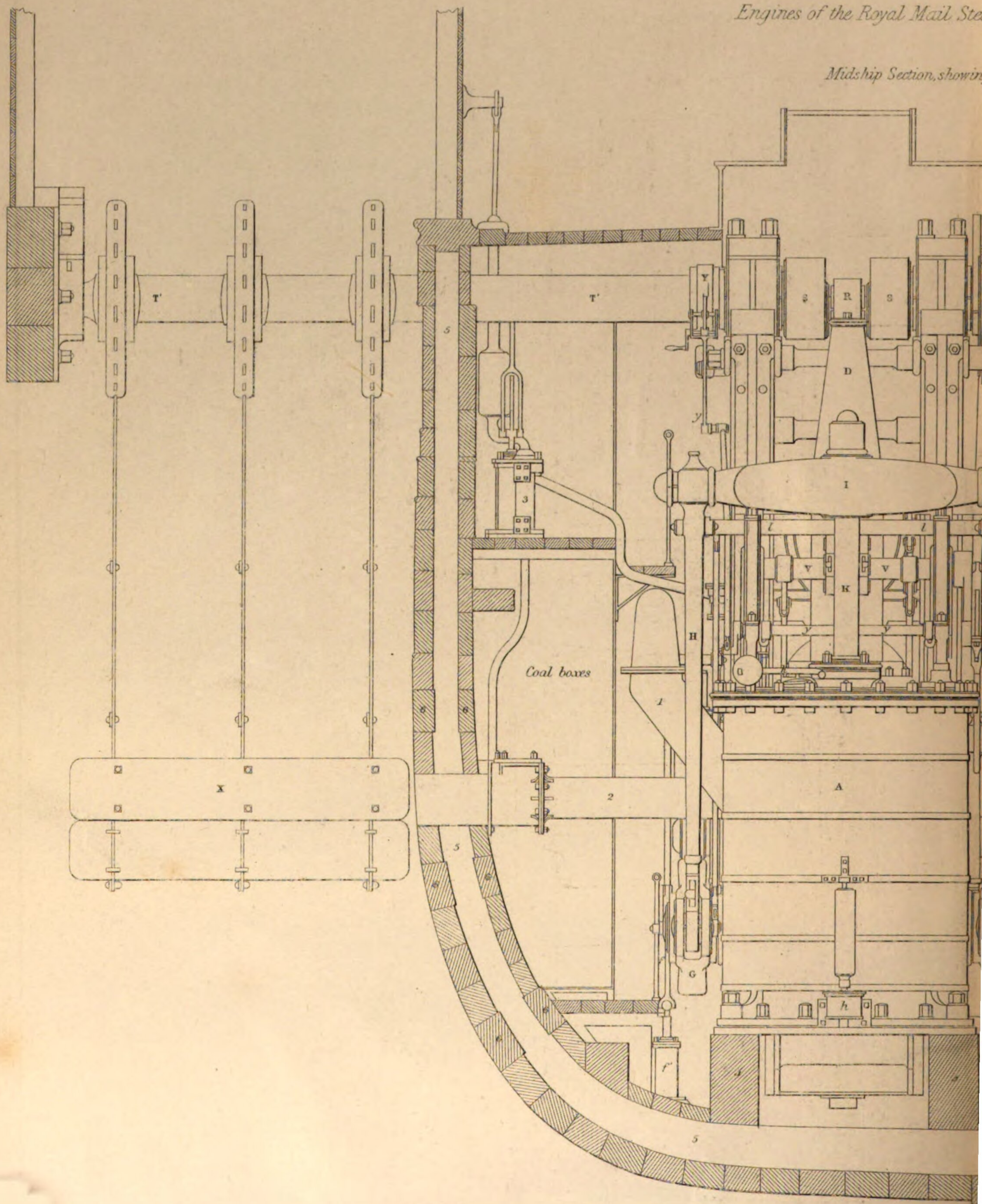
Midship Section of the Vessel



Steam Ships *Britannia*, *Acadia*, *Caledonia* and *Columbia*.

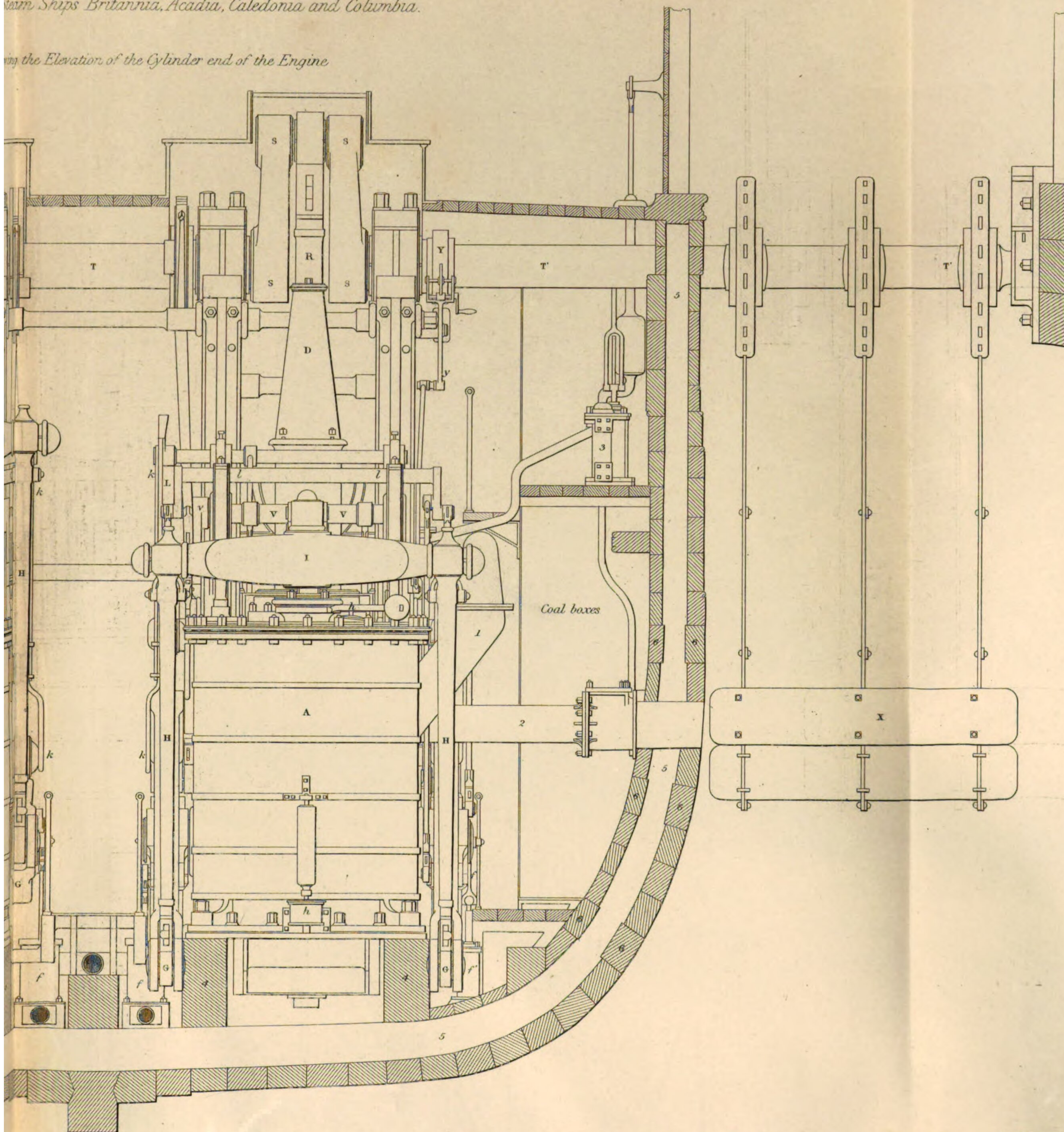
showing the Elevation of the Crank end of the Engine.



*Engines of the Royal Mail Steamer**Midship Section, showing*

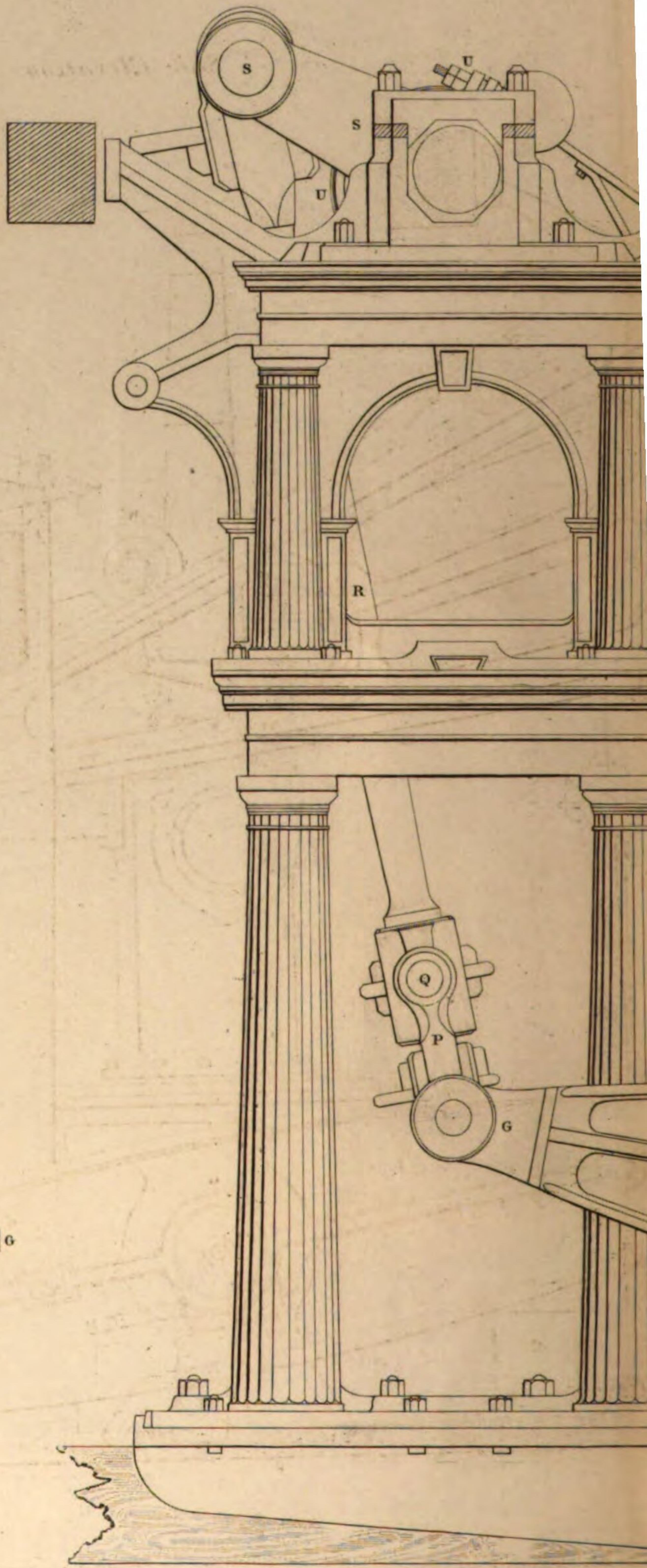
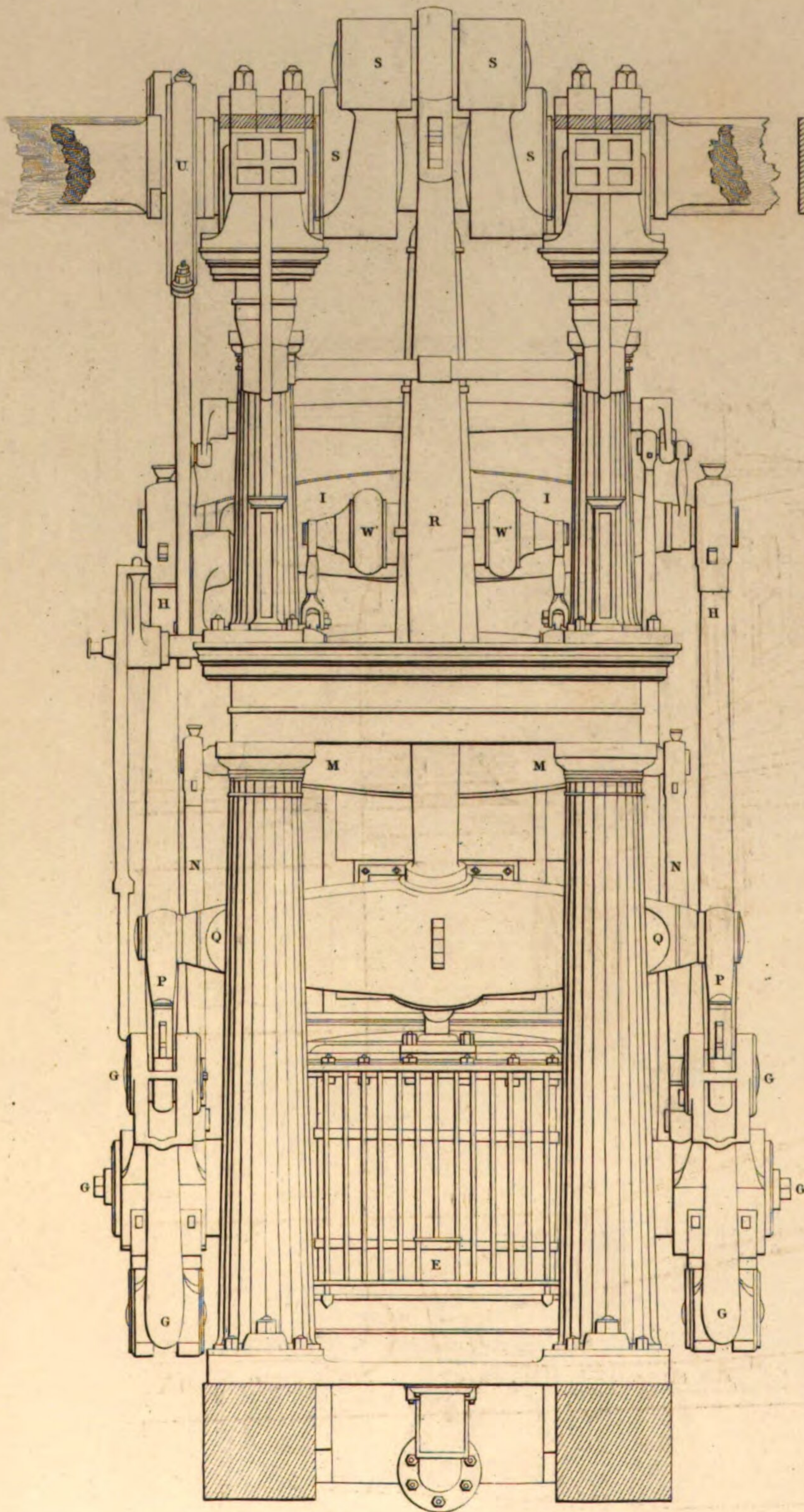
Steam Ships *Britannia, Acadia, Caledonia and Columbia.*

Showing the Elevation of the Cylinder end of the Engine



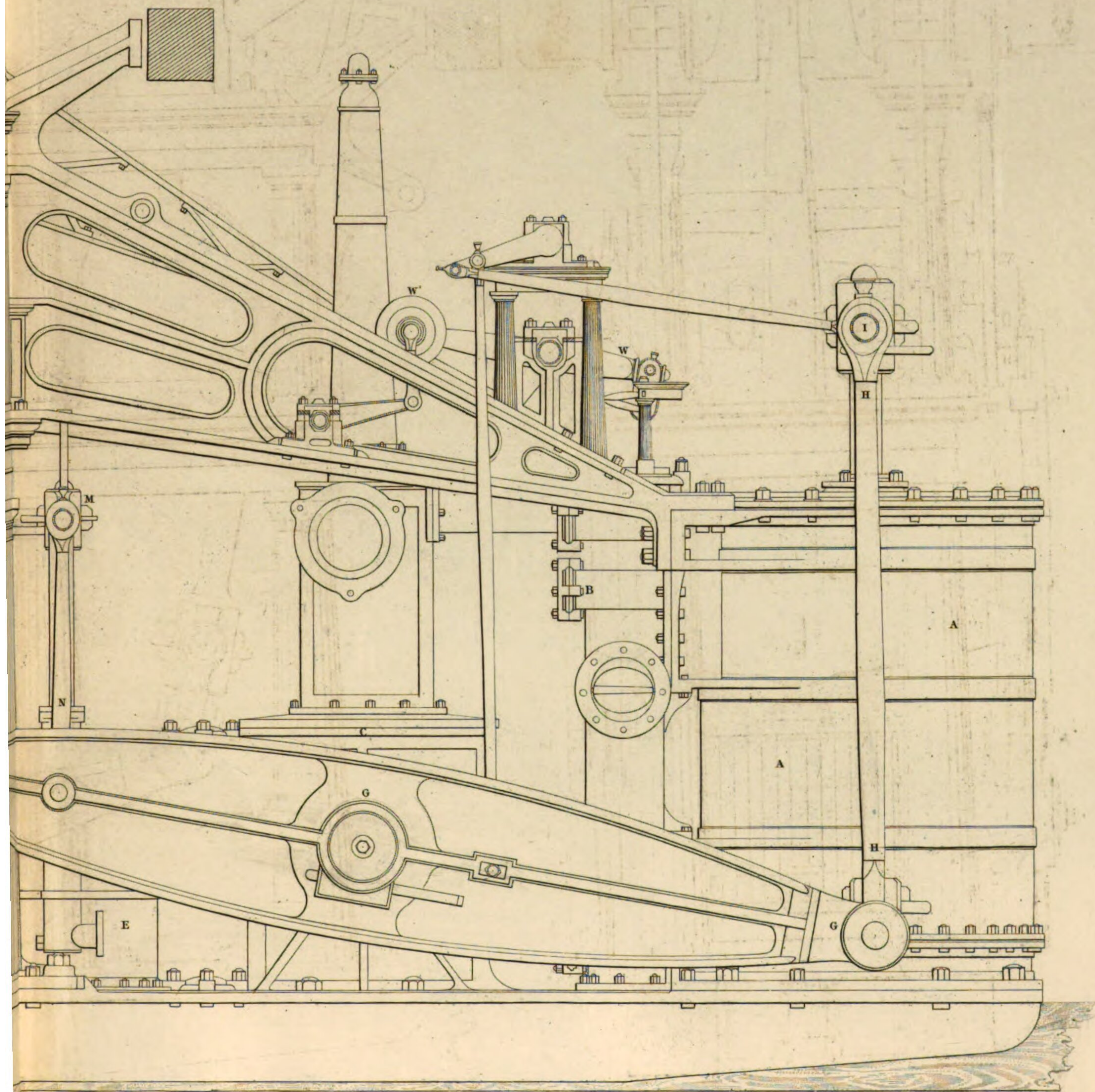
End Elevation.

Engine of H.M.



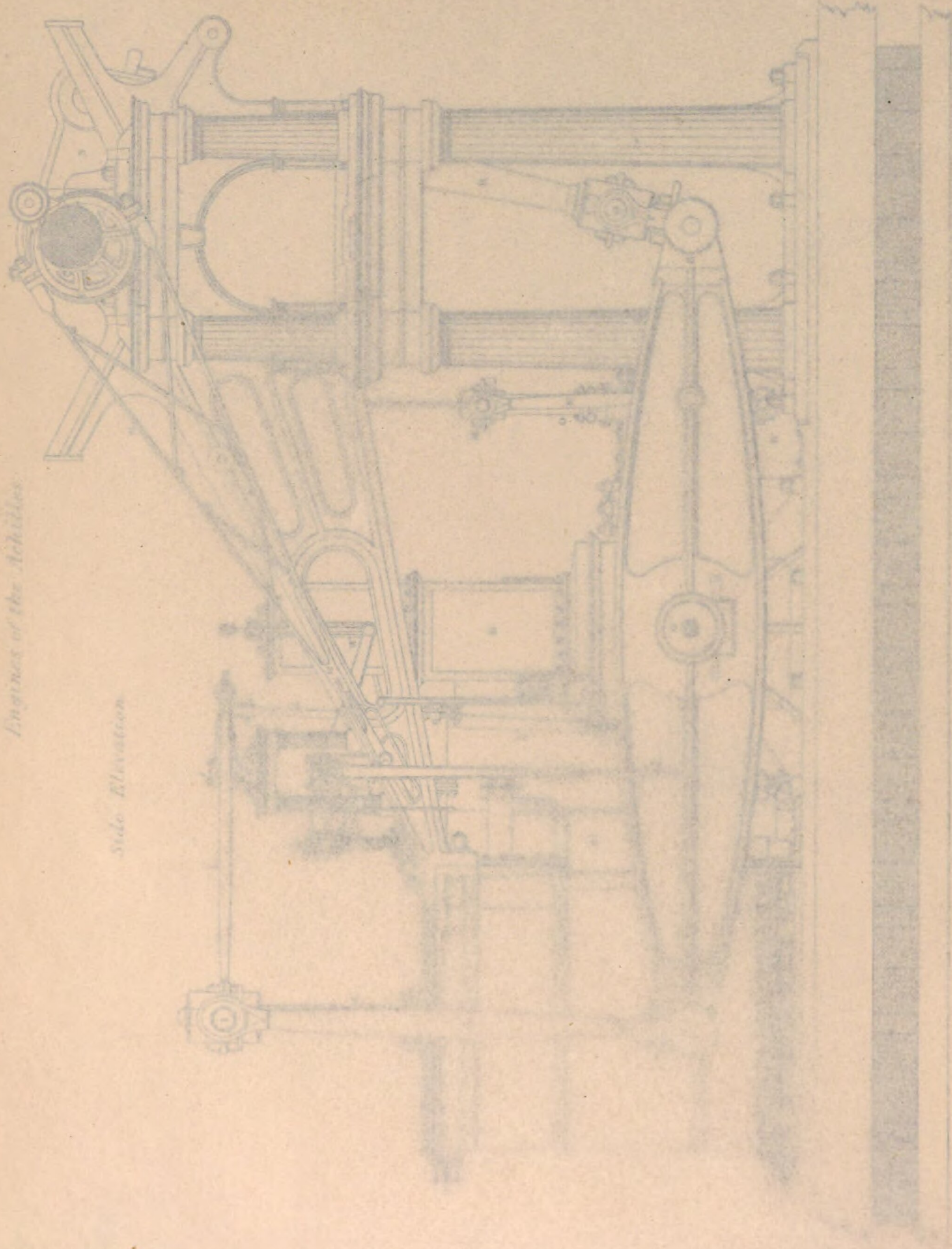
Oil Packet Urgent.

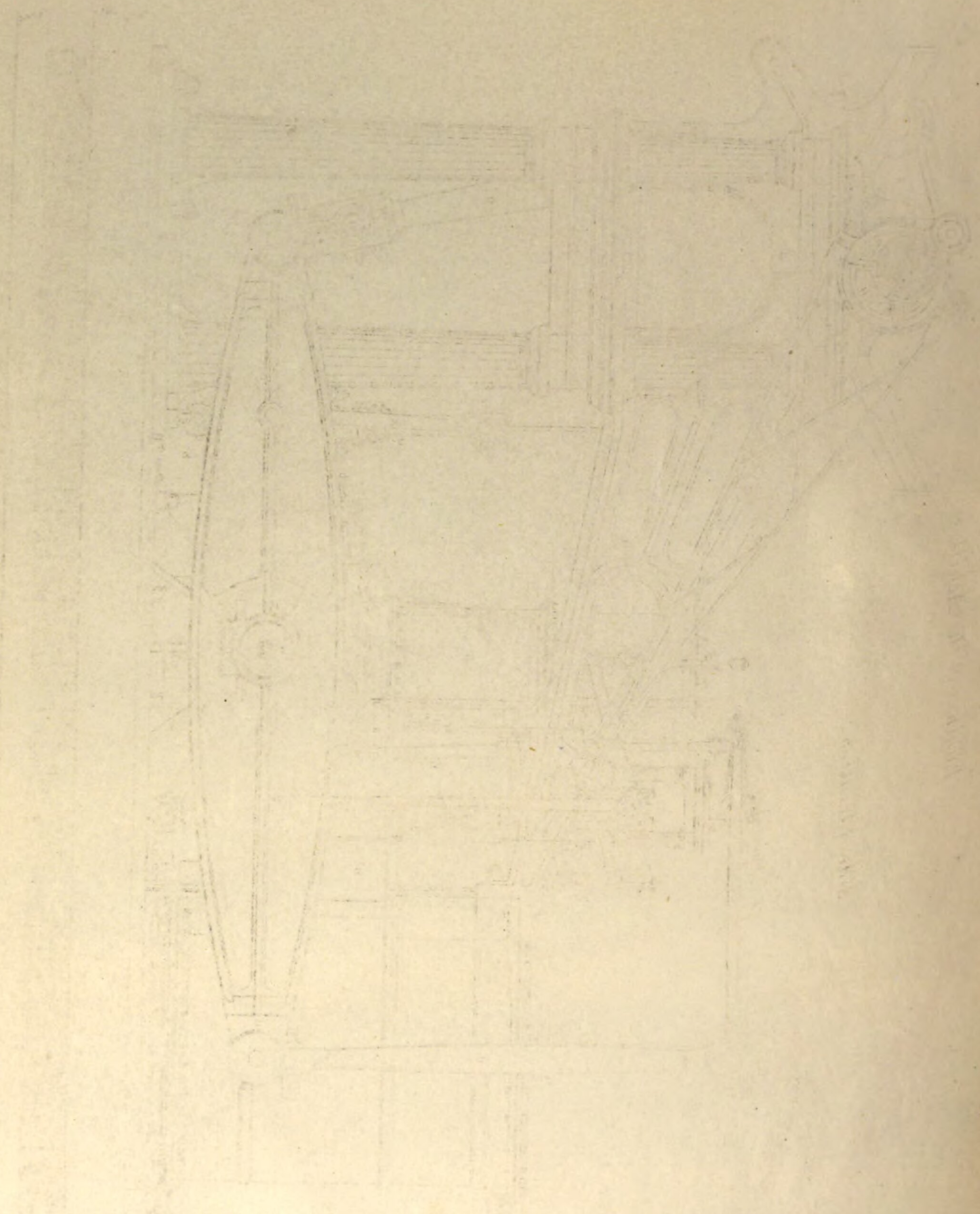
Side Elevation.



Engines of the Achilles

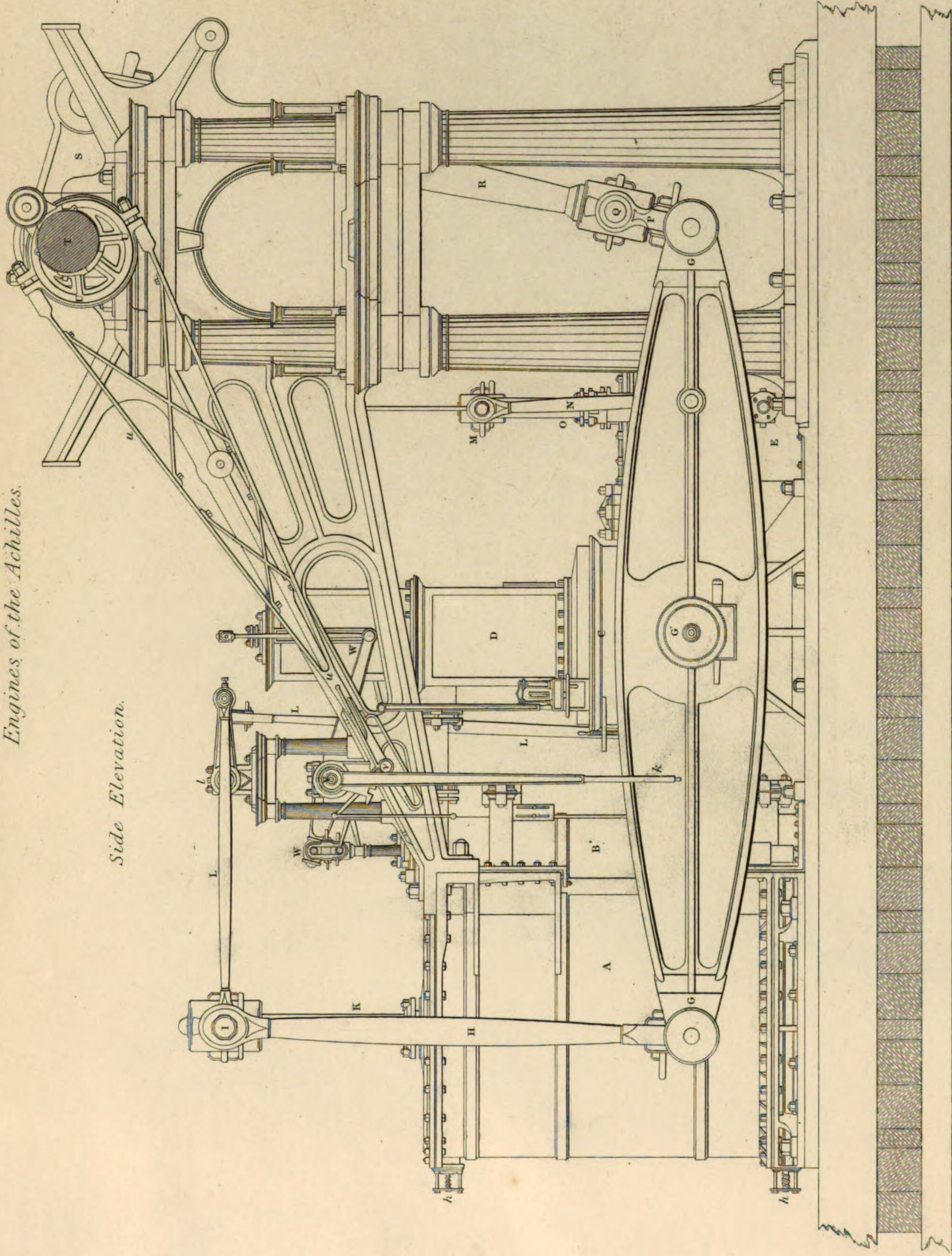
Side Elevation

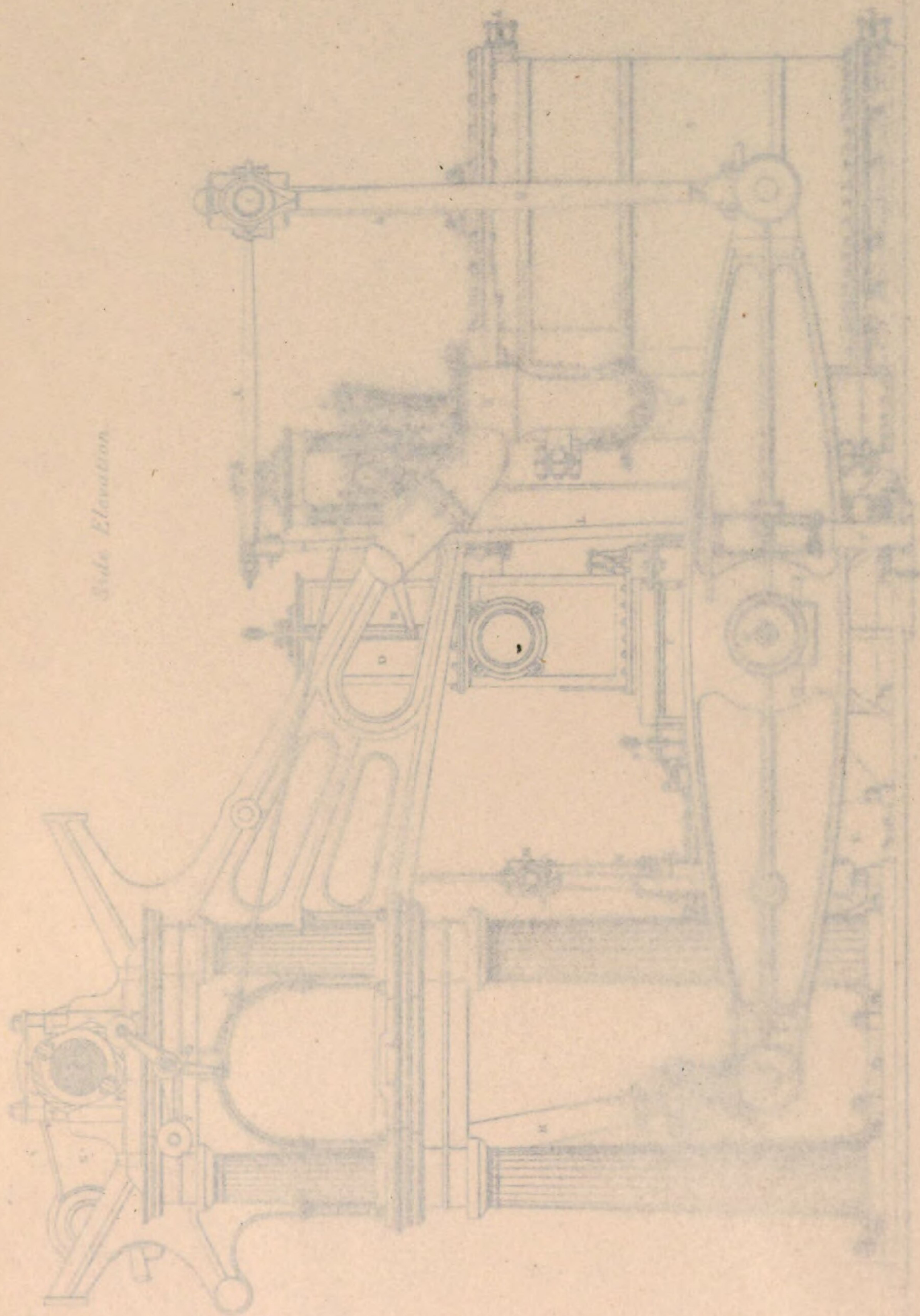


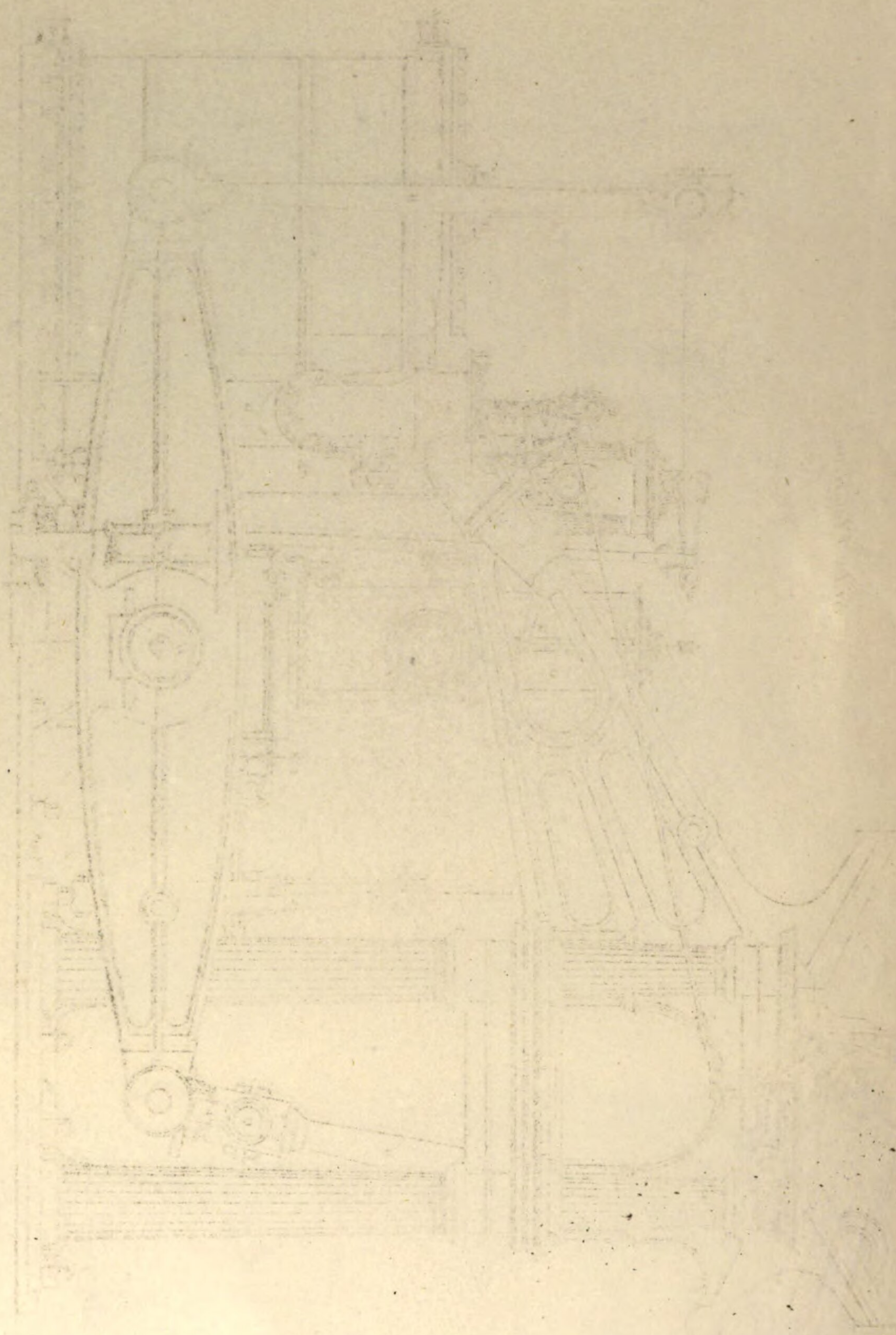


Engines of the Achilles.

Side Elevation.

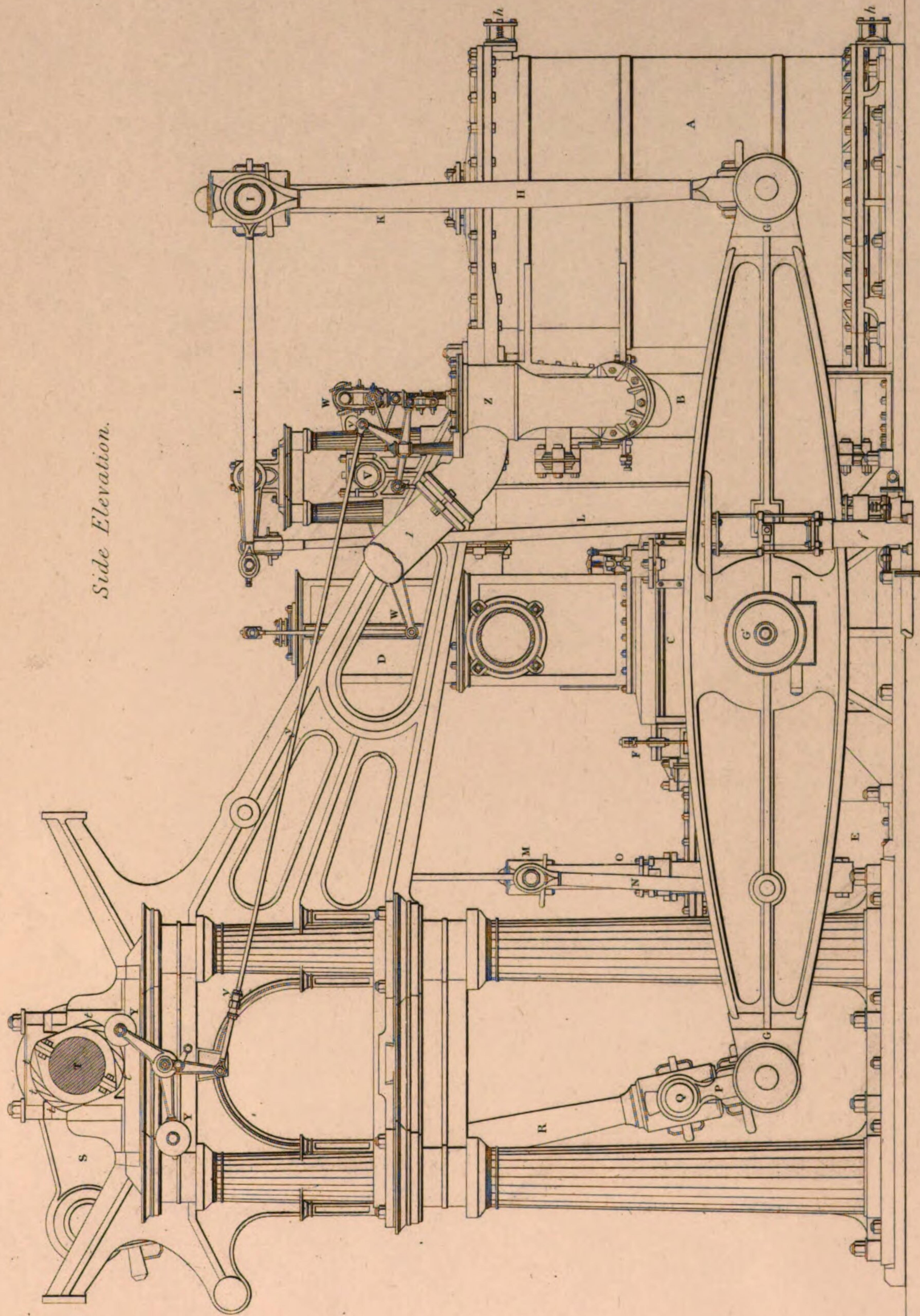


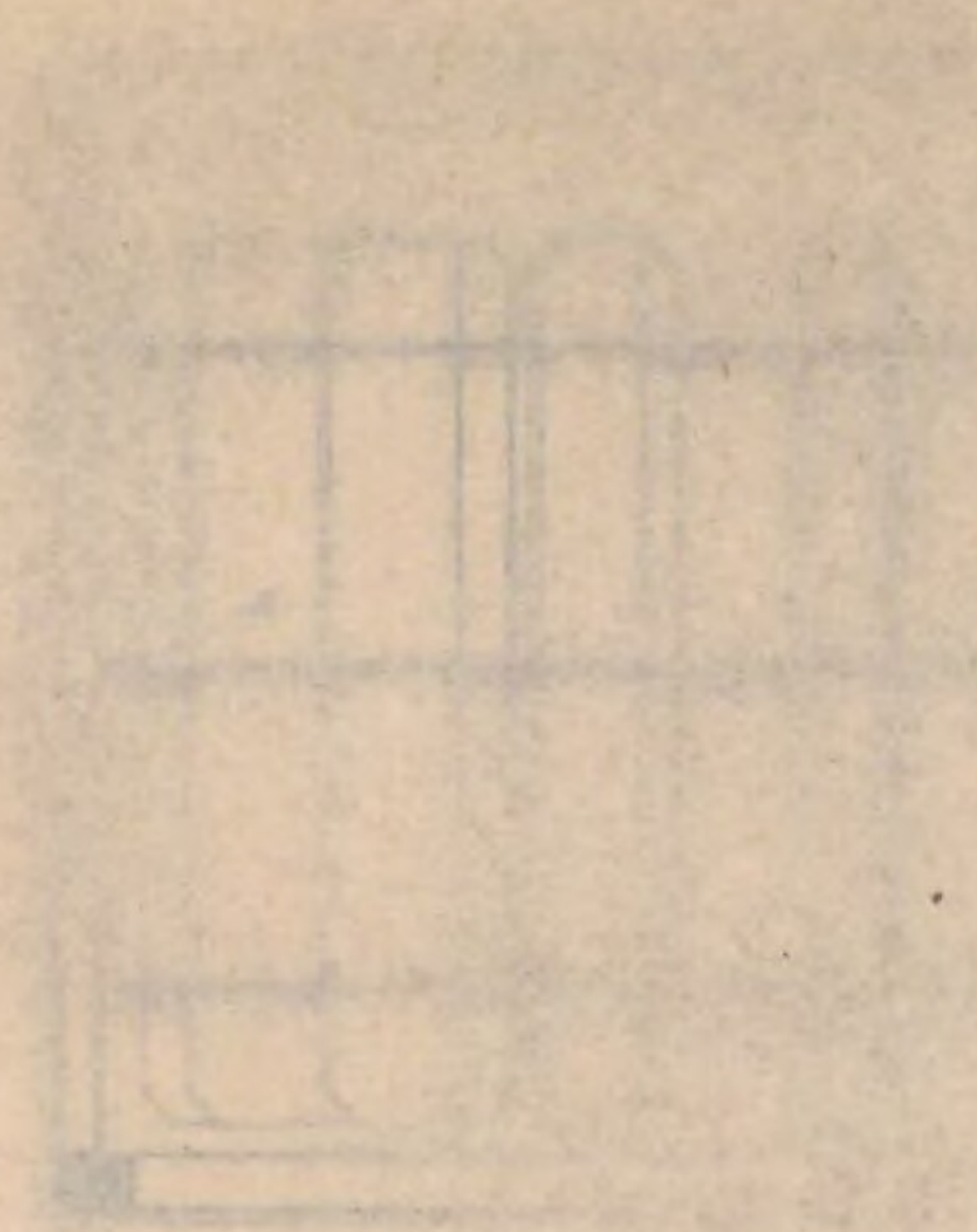




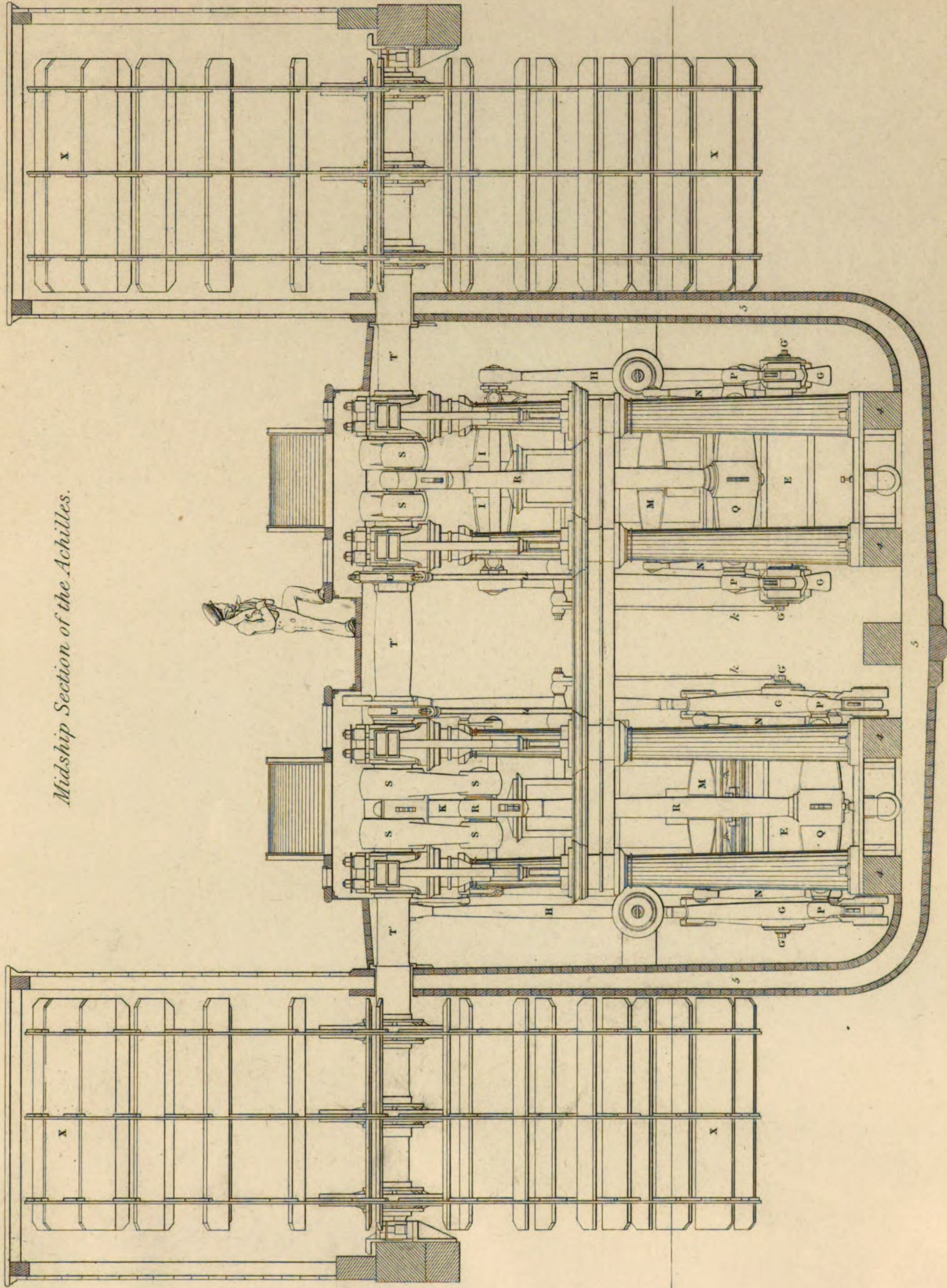
Engines of the Achilles.

Side Elevation.



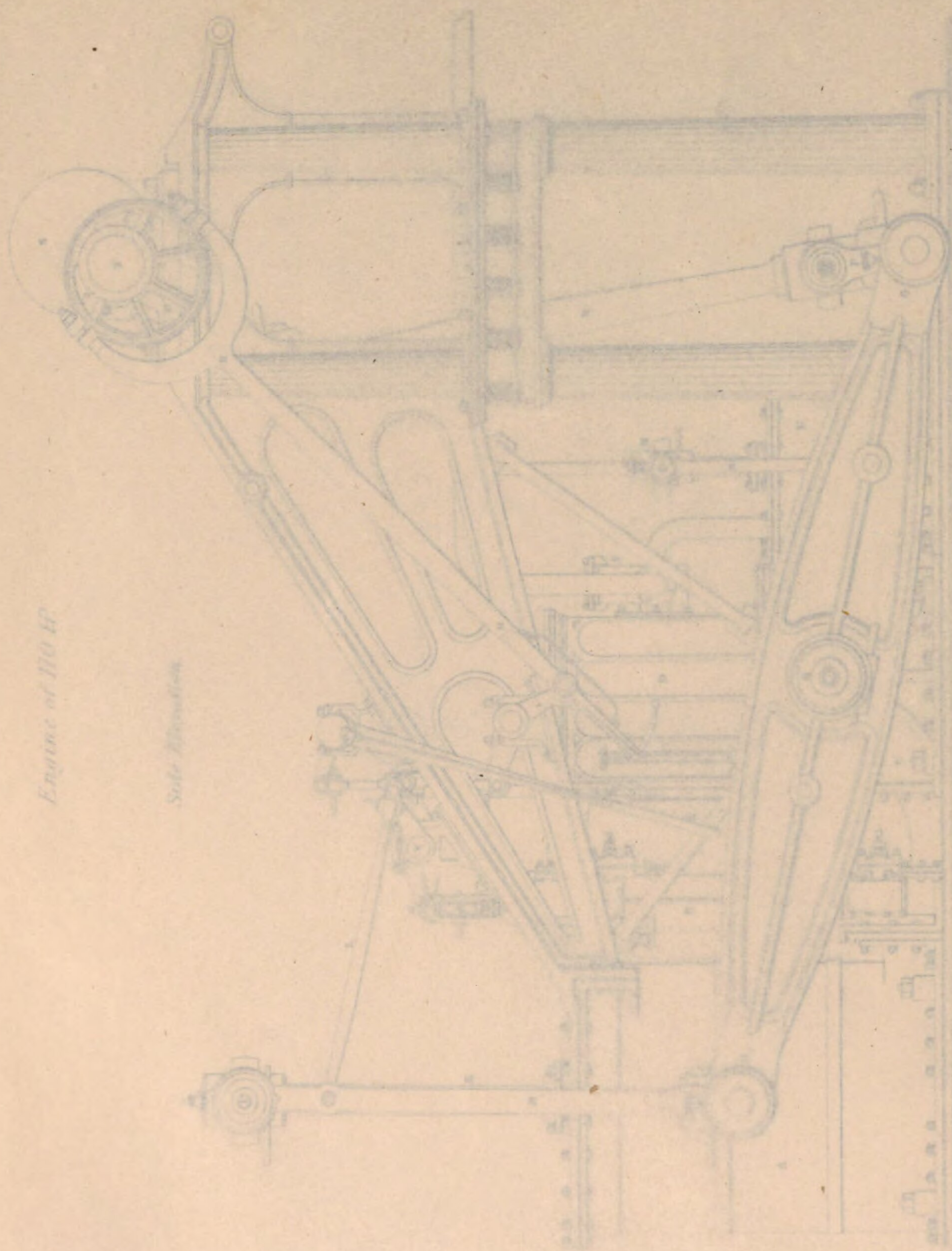


Midship Section of the Achilles.



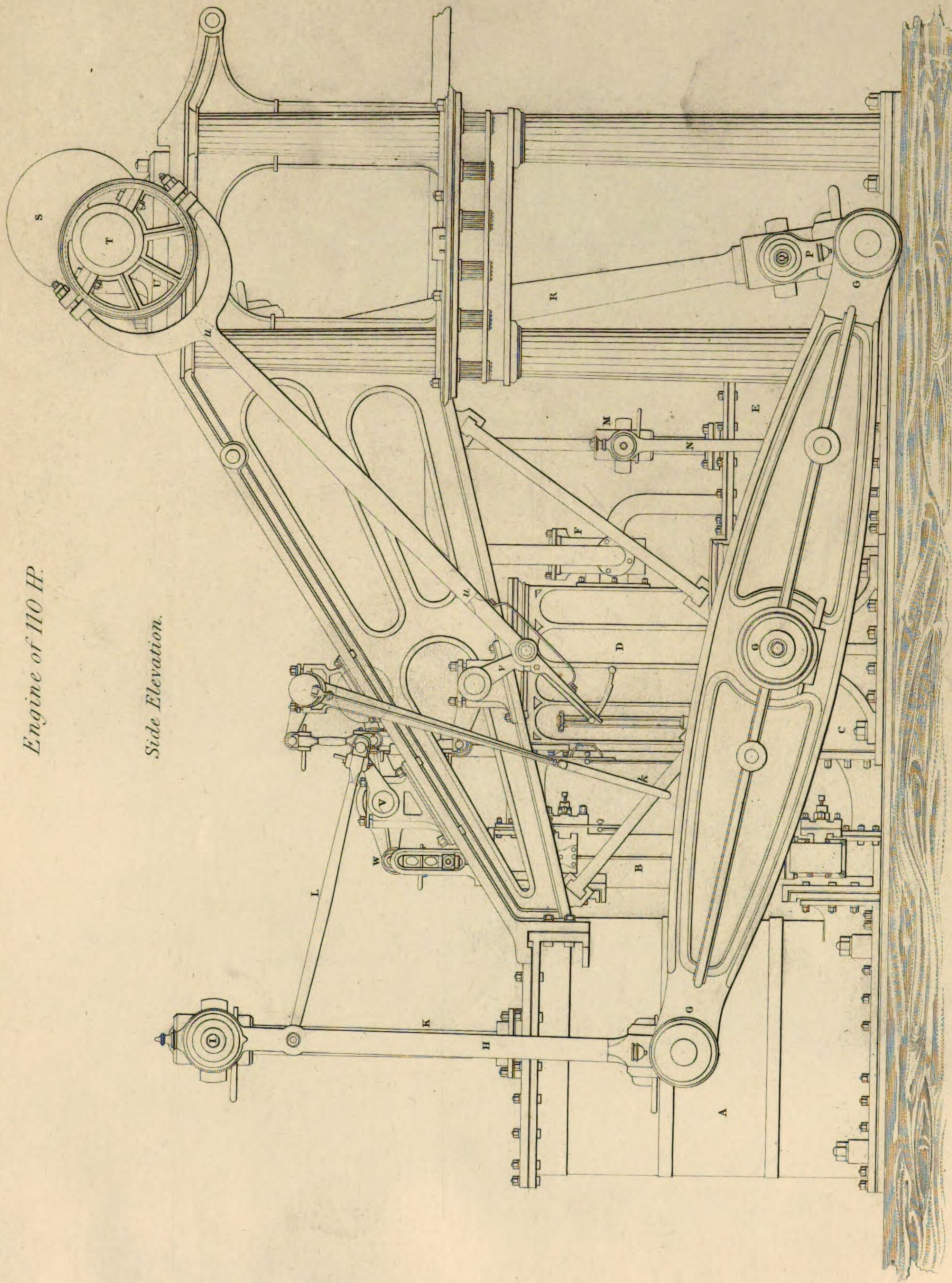
Engine of 110 H.P.

Side Elevation.



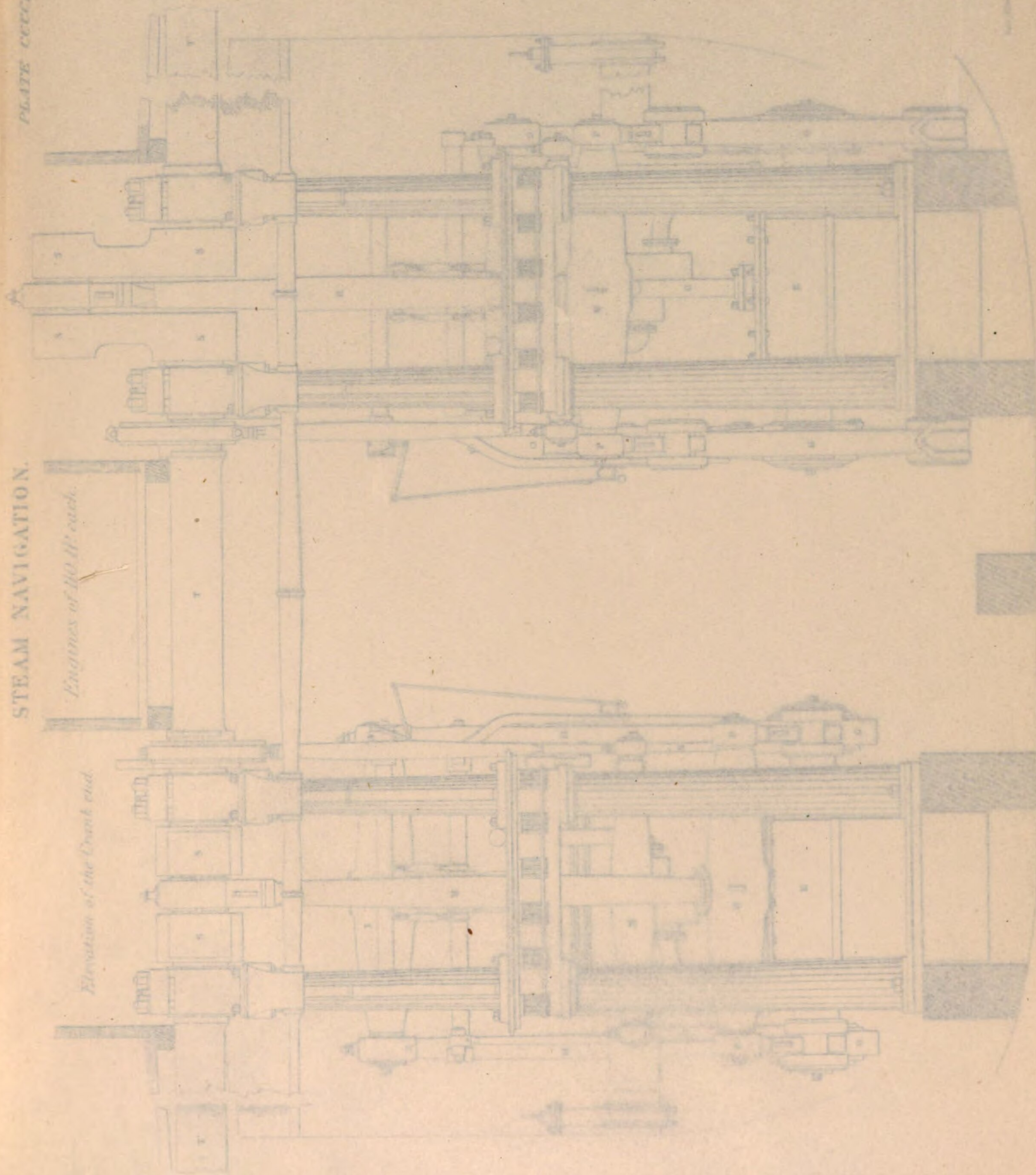
Engine of 110 H.

Side Elevation.



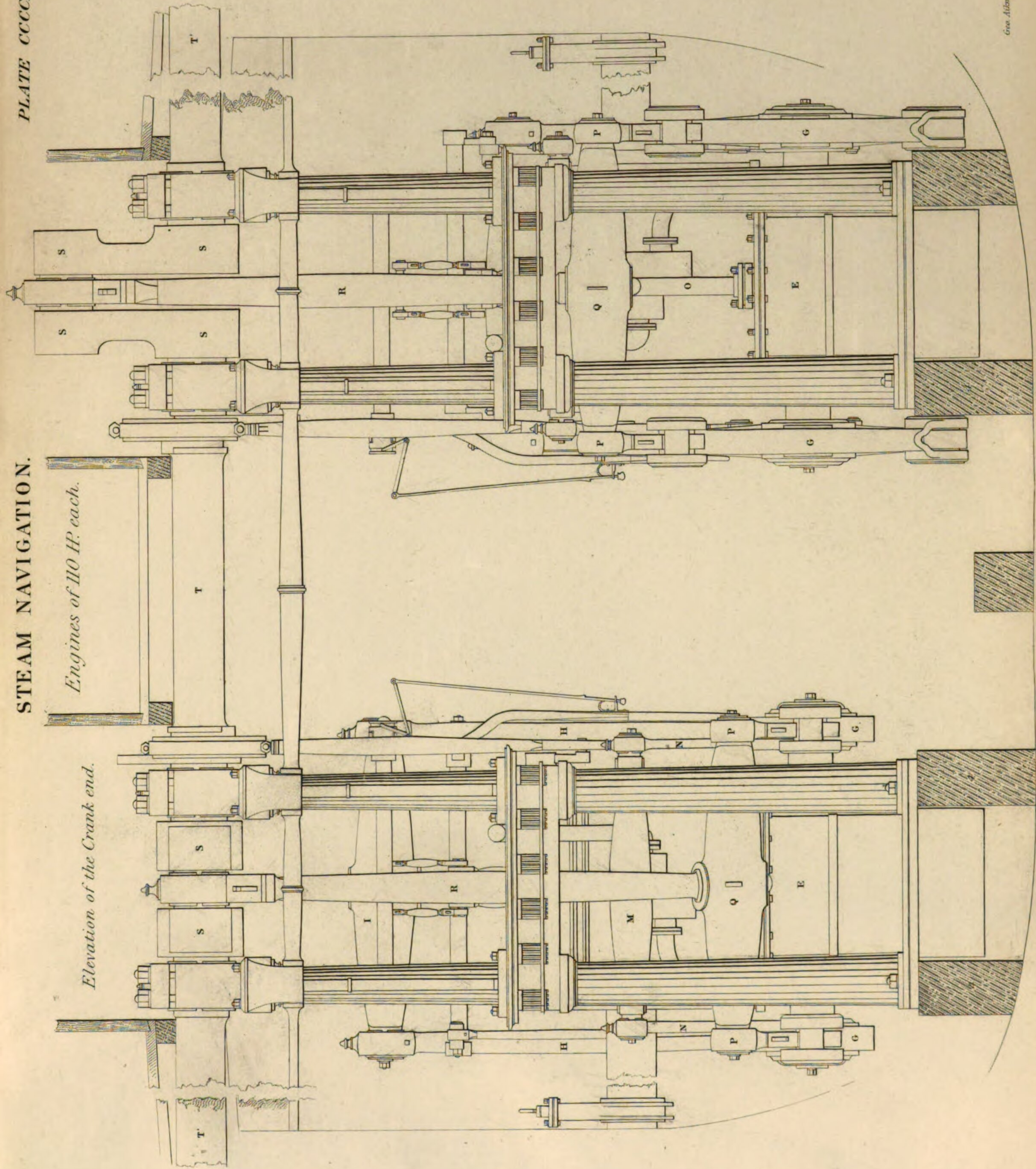
Engines of 110 H.P. each.

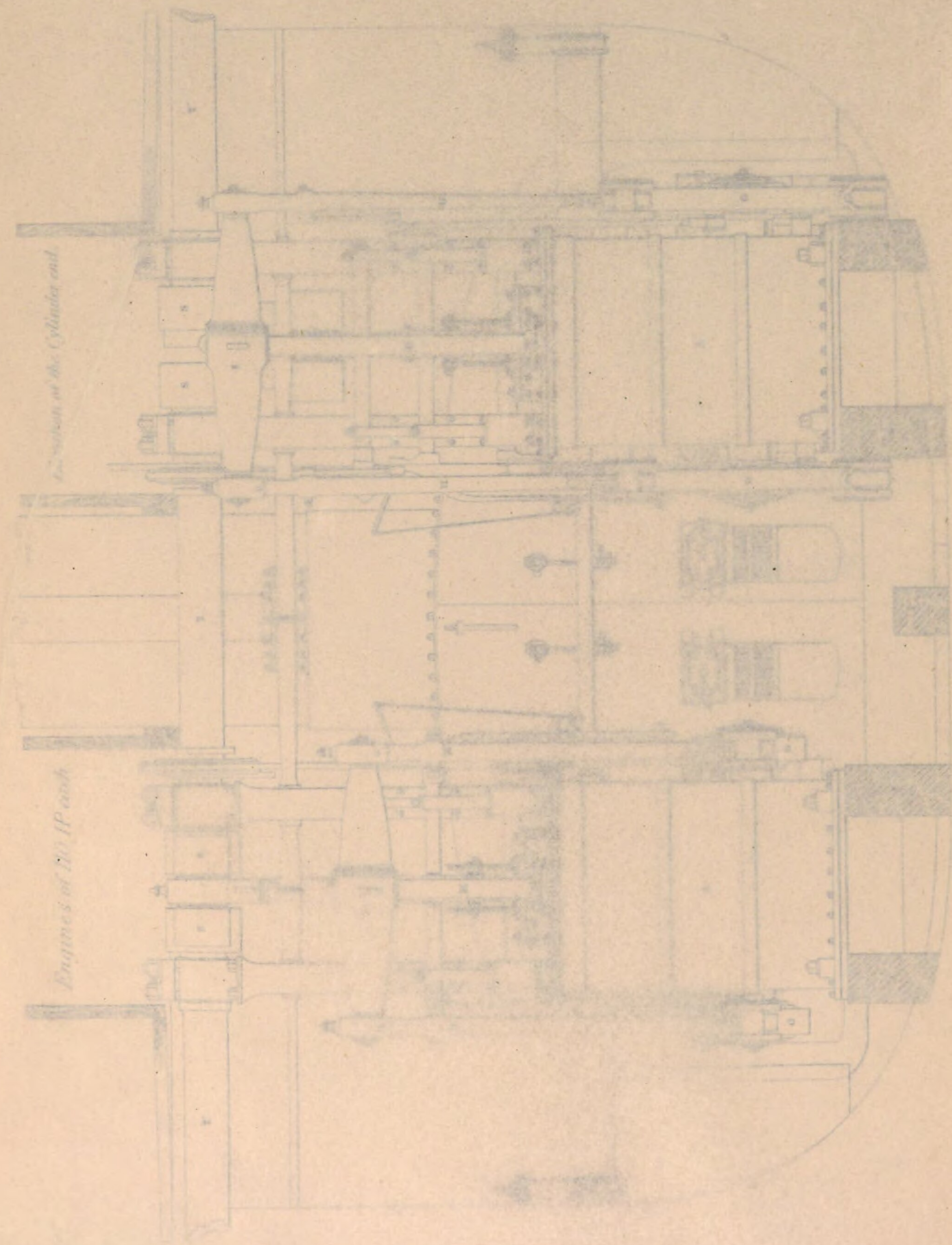
Elevation of the Crank end.



Engines of 110 H.P. each.

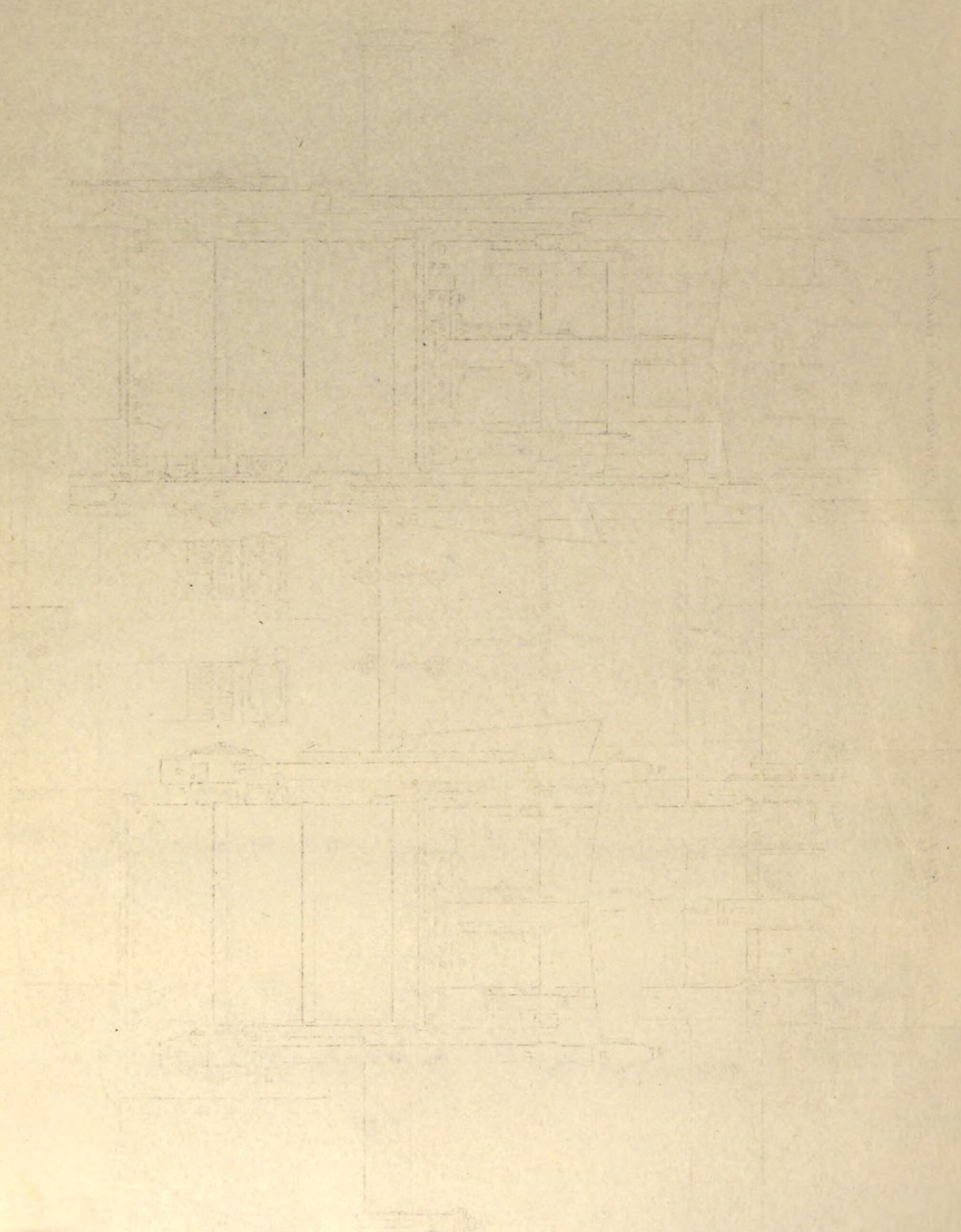
Elevation of the Crank end.





Engines of 200 HP each

Section of the Cylinder end



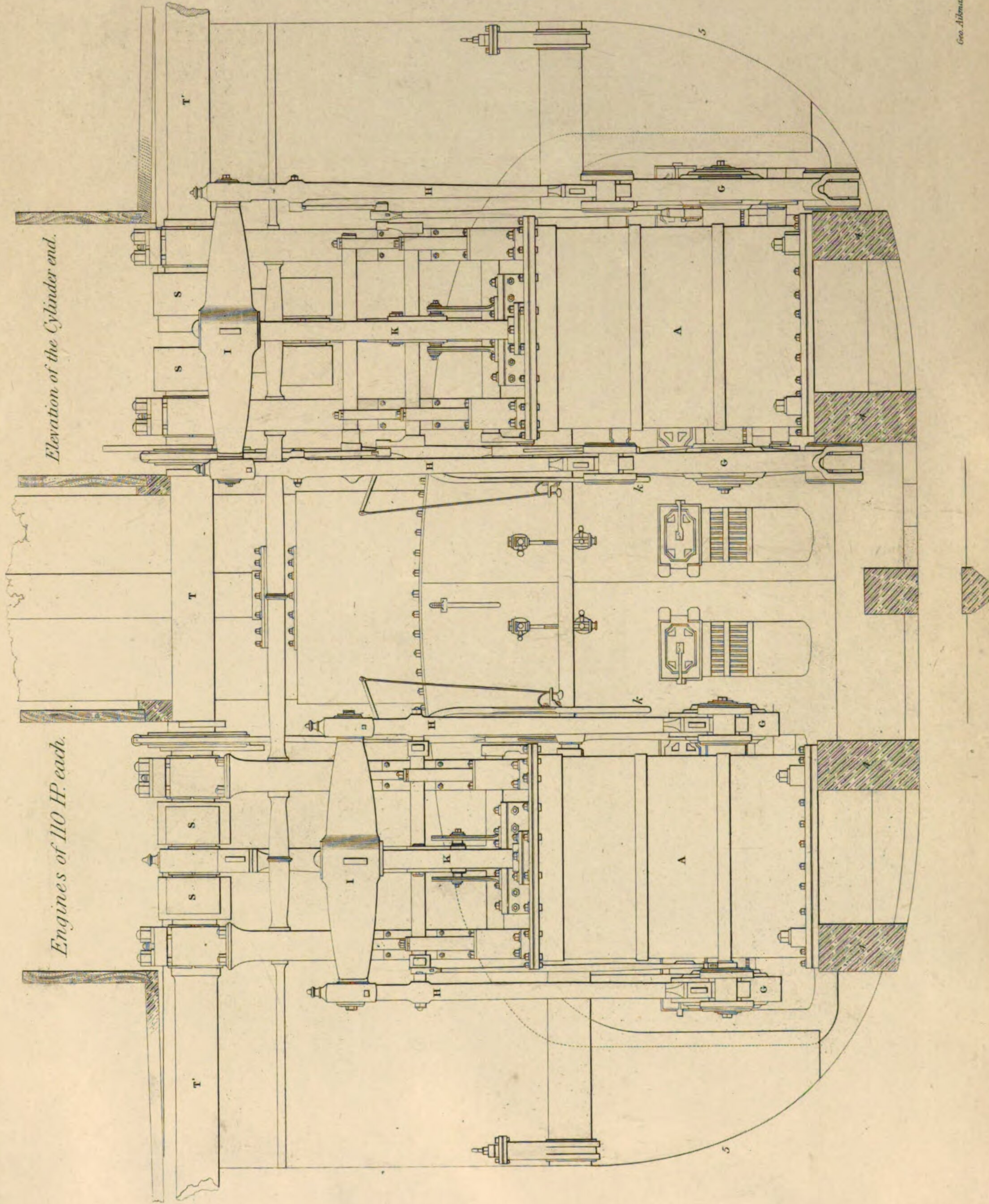
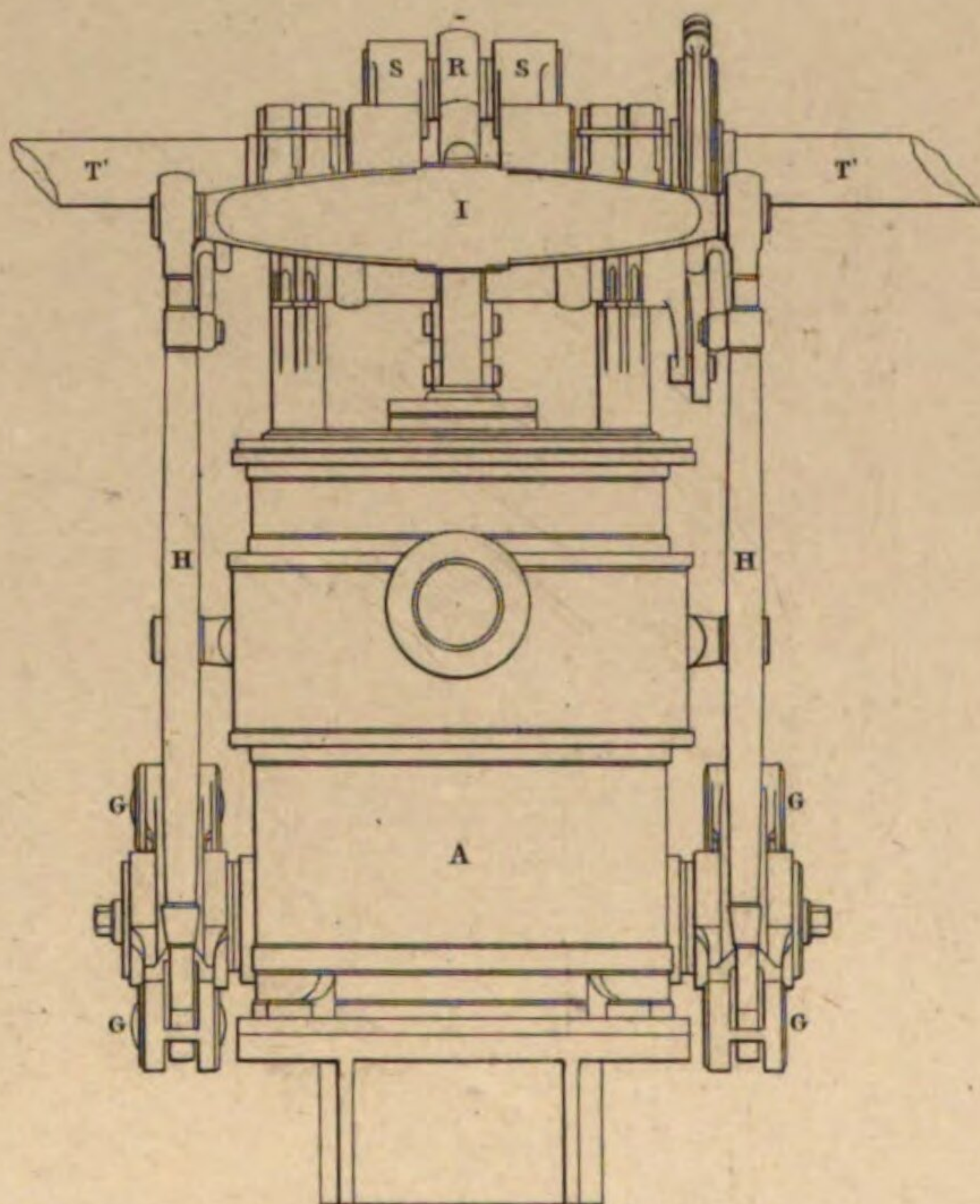


Fig. 3.



Elevation of the Cylinder end.

Fig. 1.

Side Ele

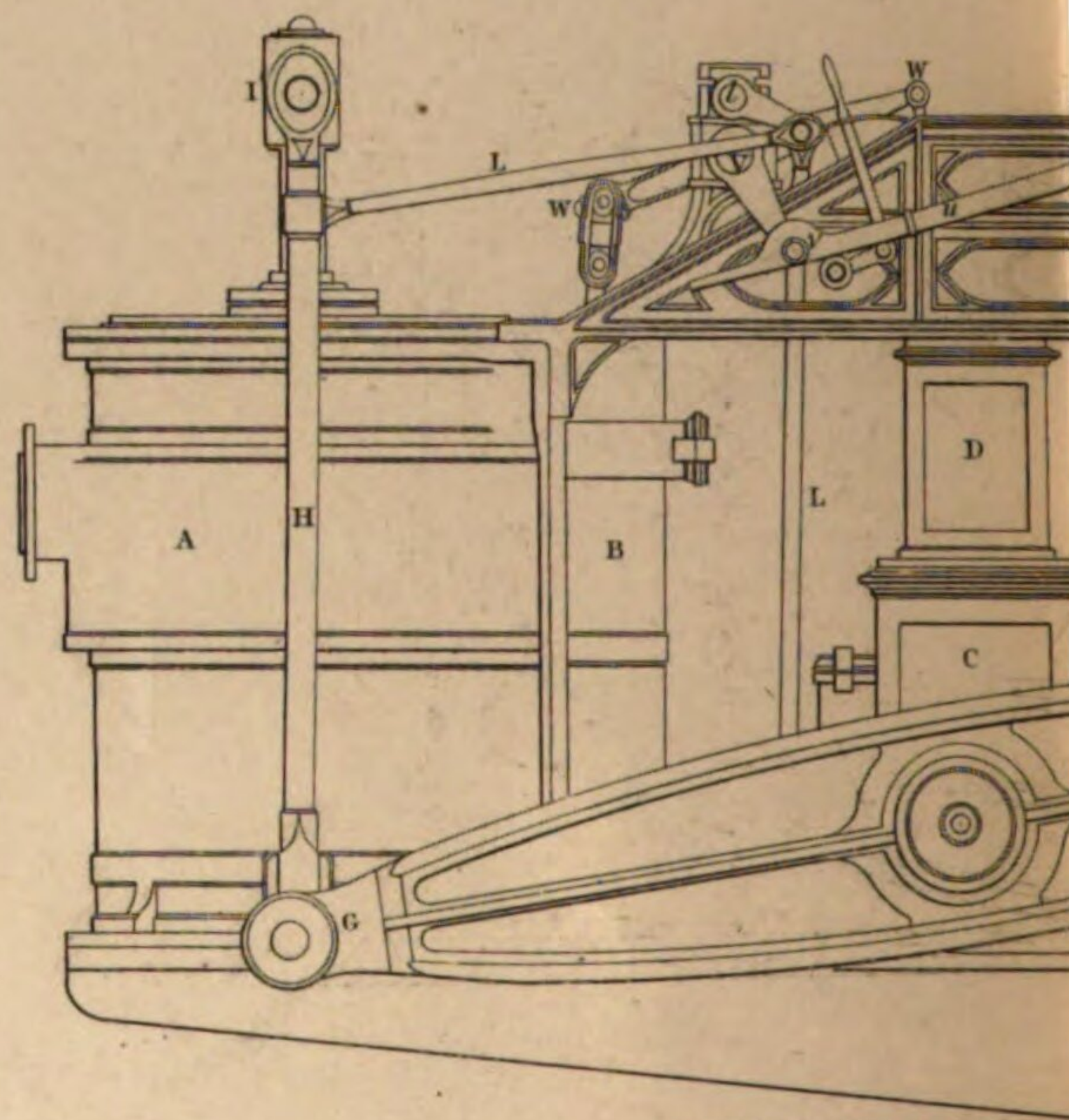
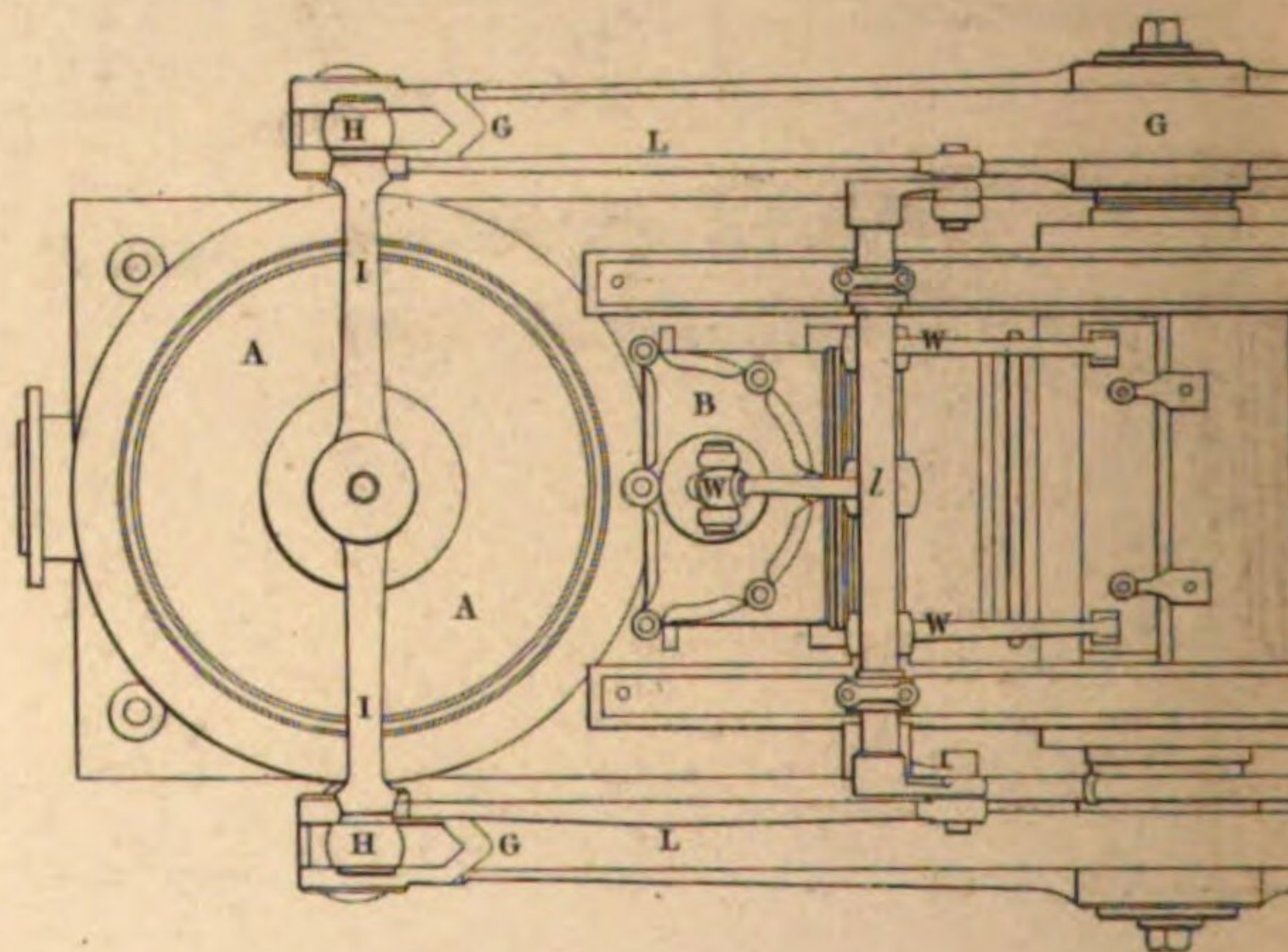


Fig. 2.



Plan.

Engine of 65 H.P.

Fig. 4.

Elevation.

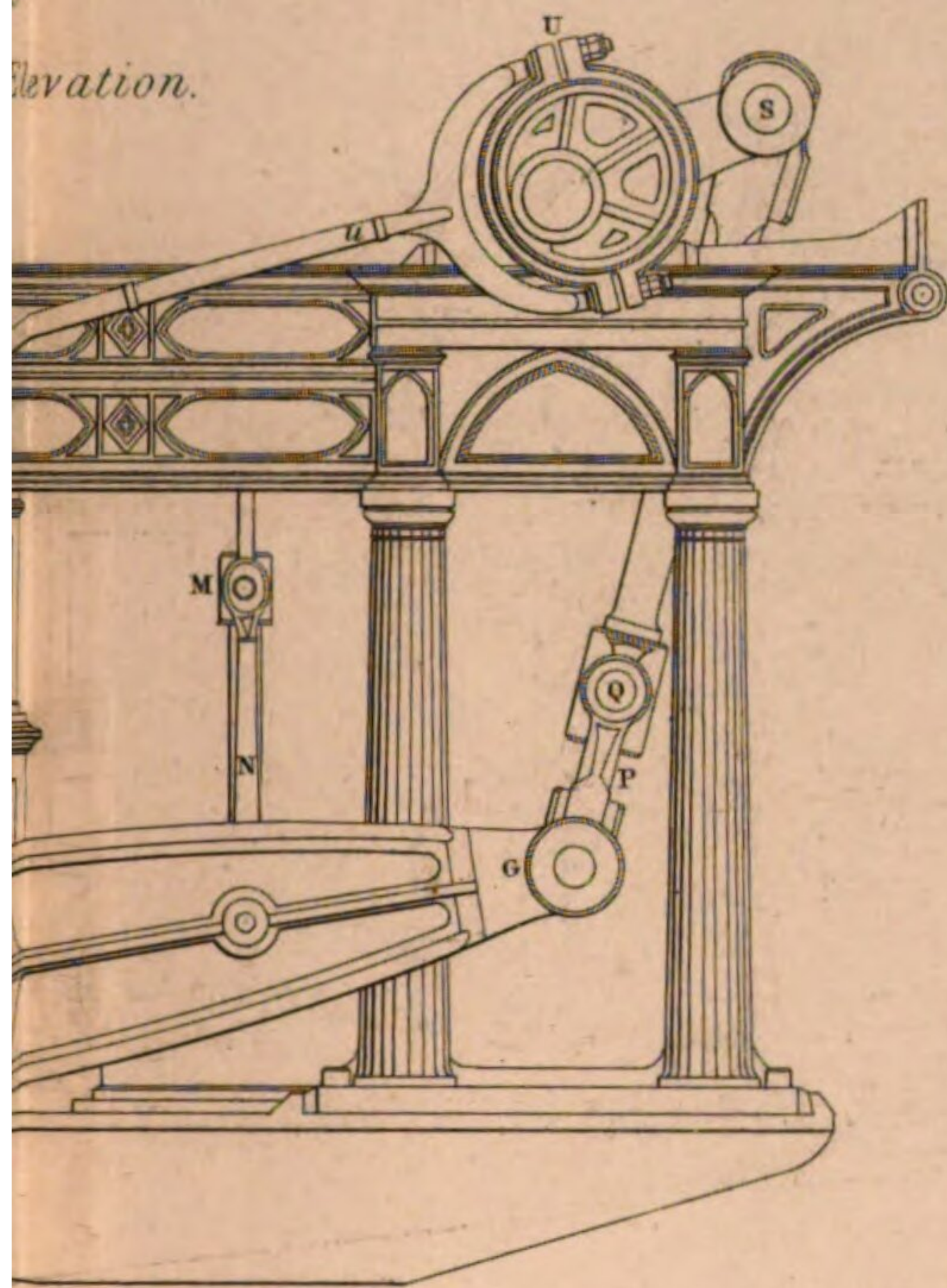
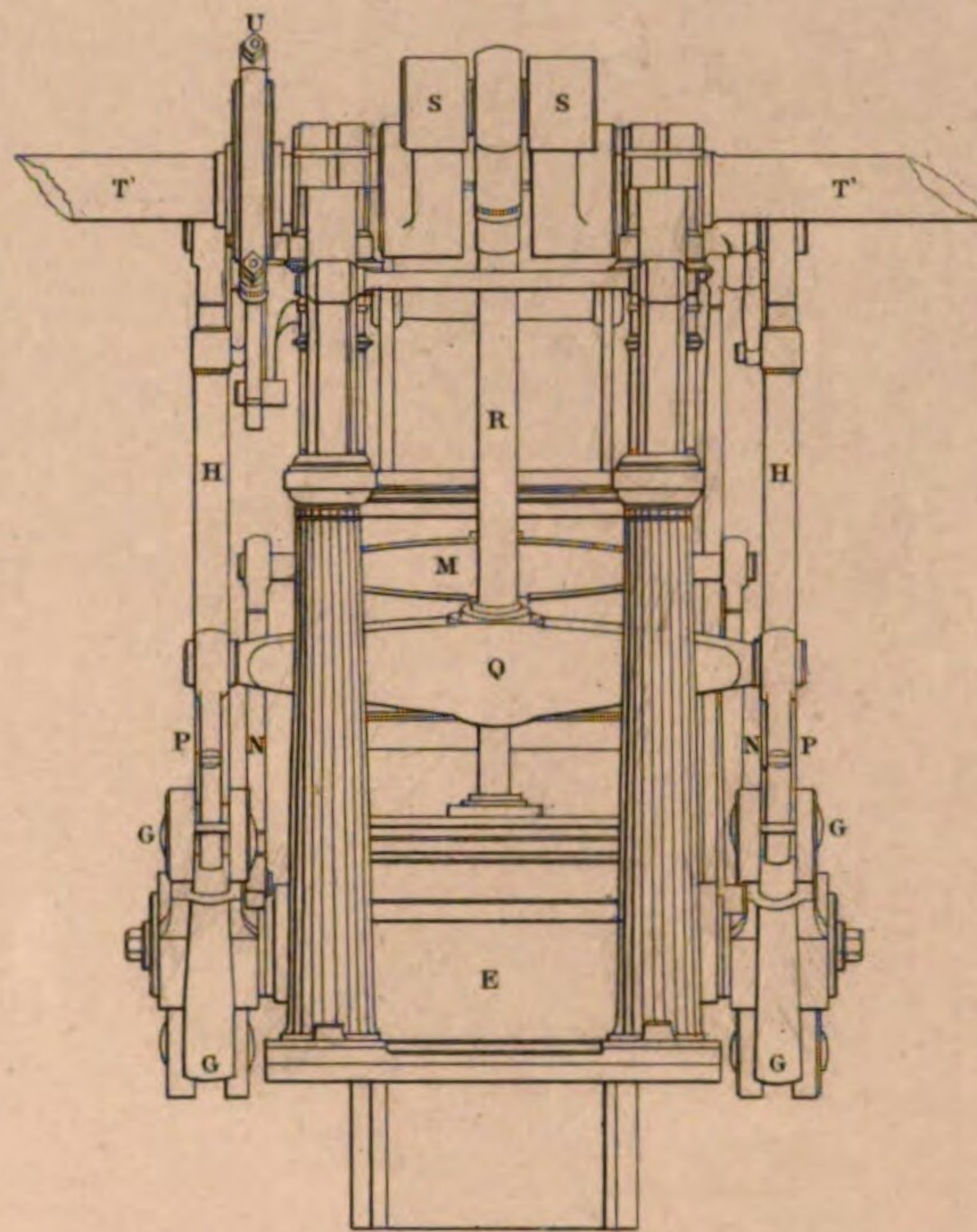
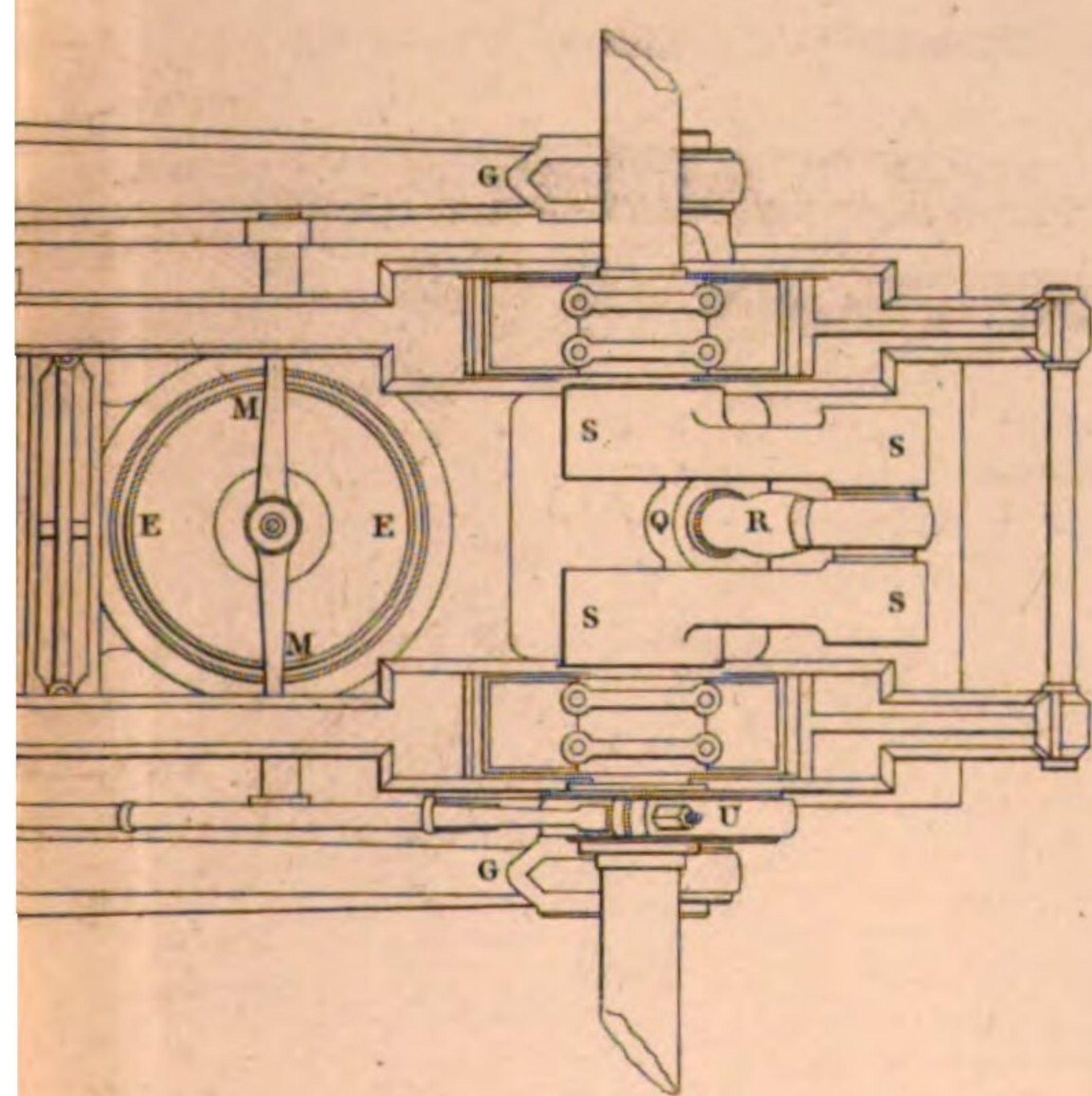


Fig. 4.

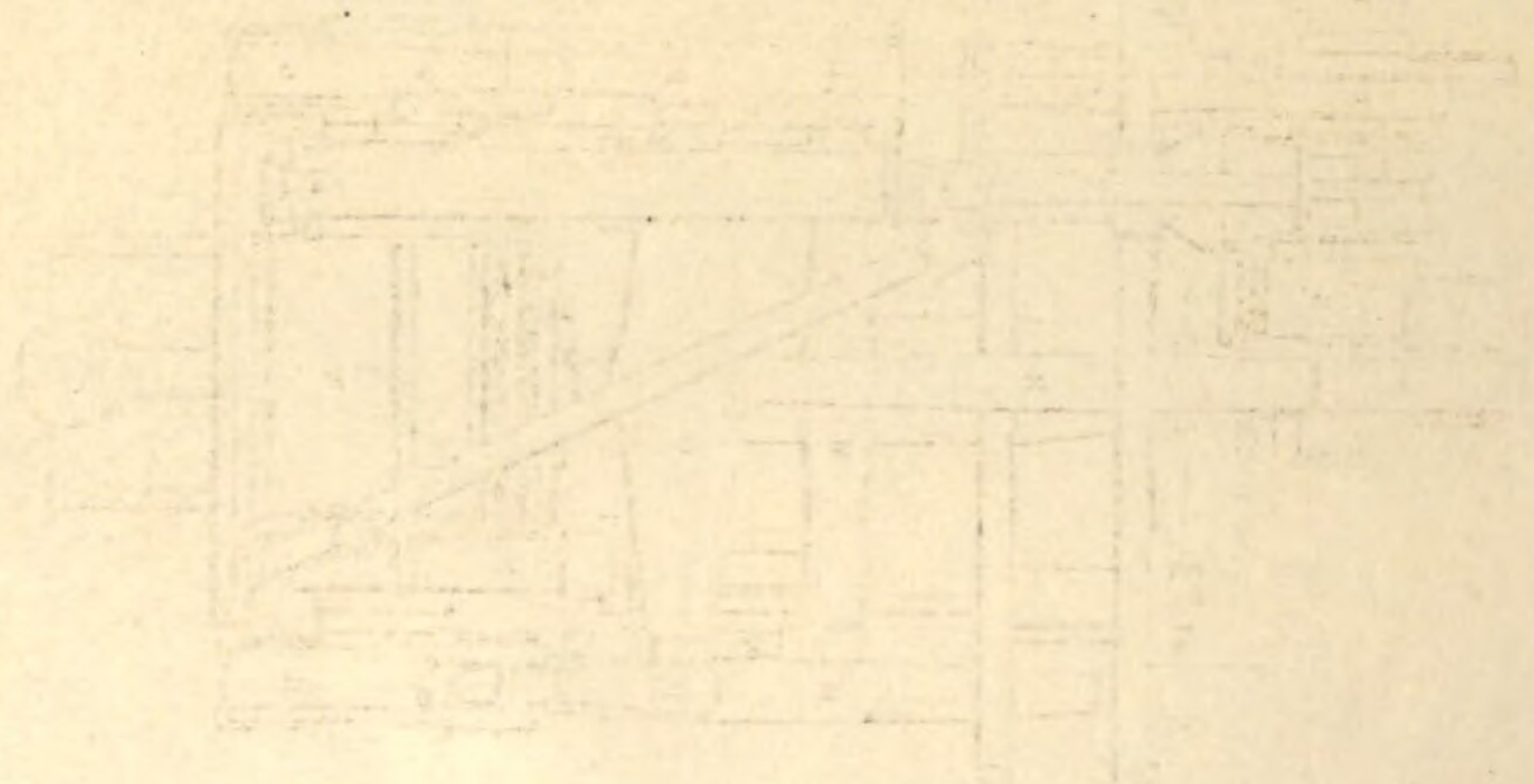
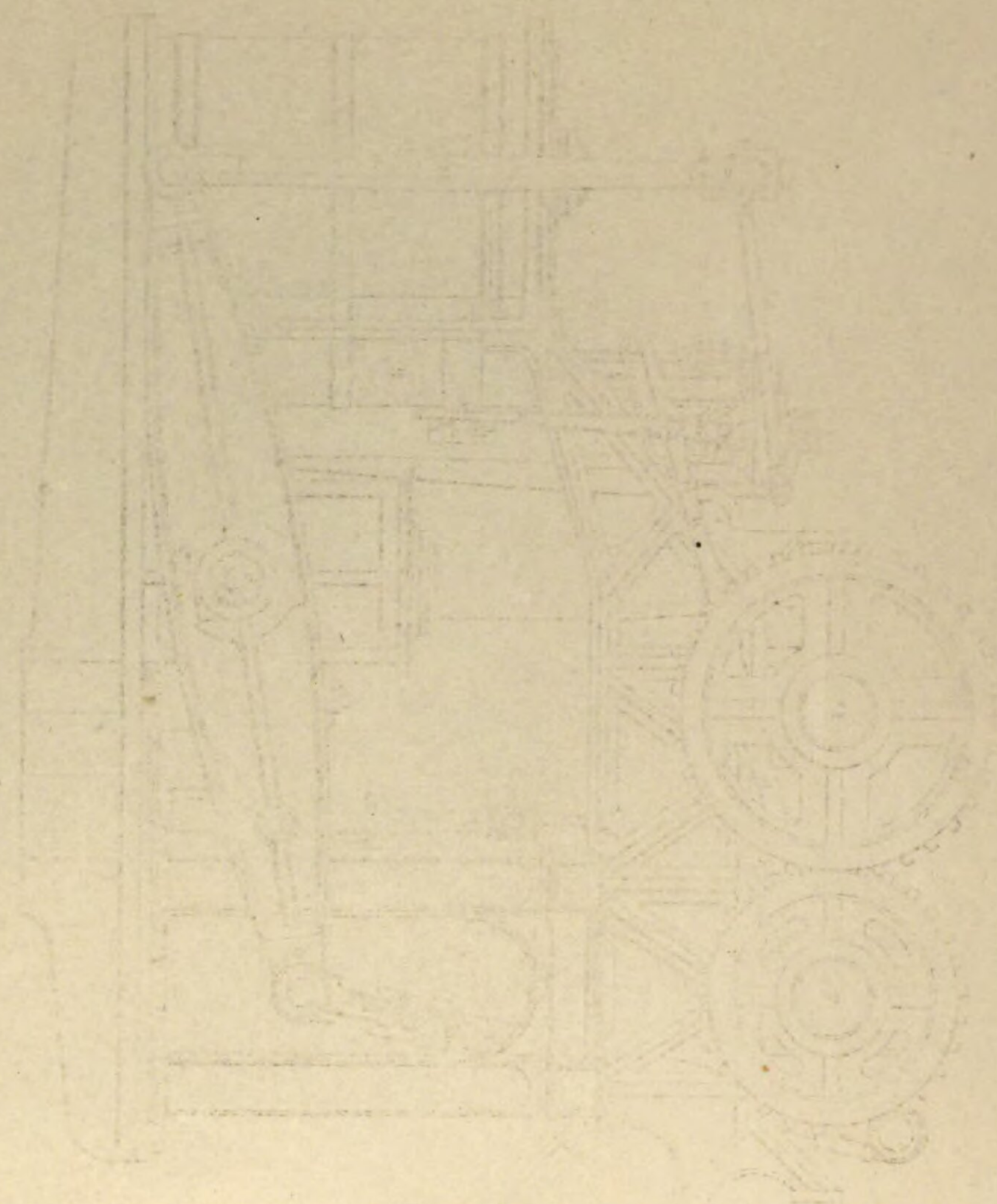


Elevation of the Crank end.

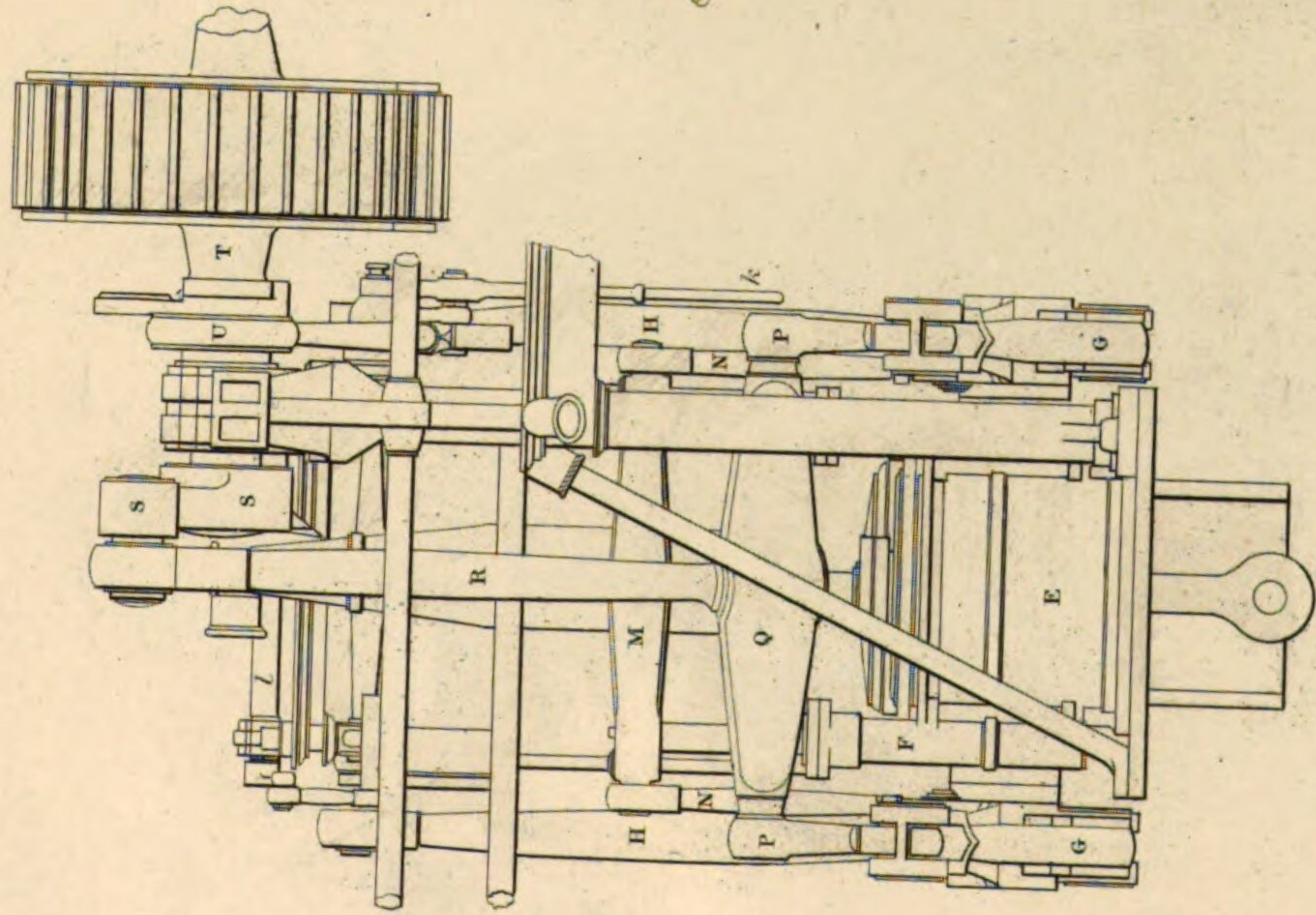


Double Towing Engine of 45 HP

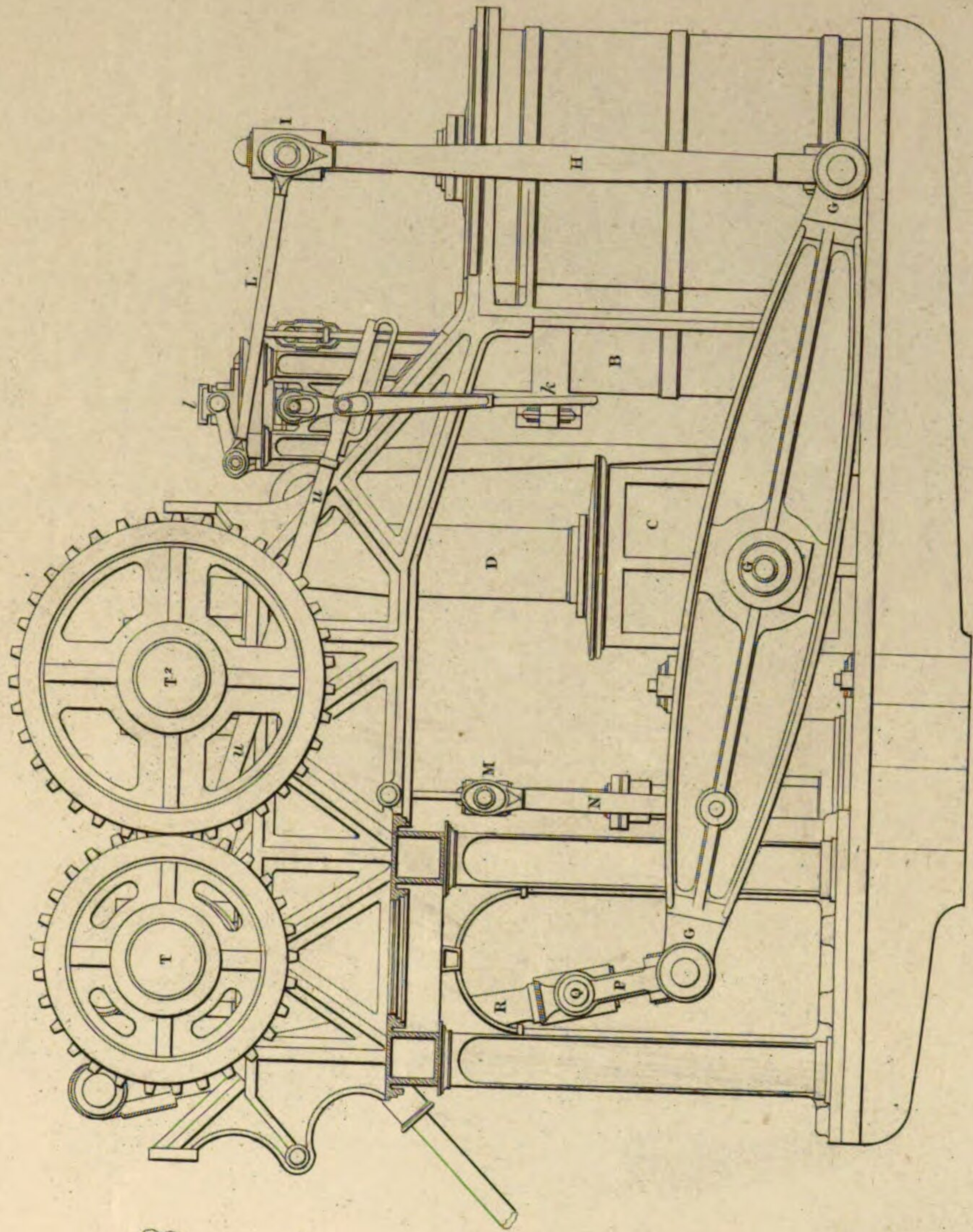




Double Towing Engine of 45 HP

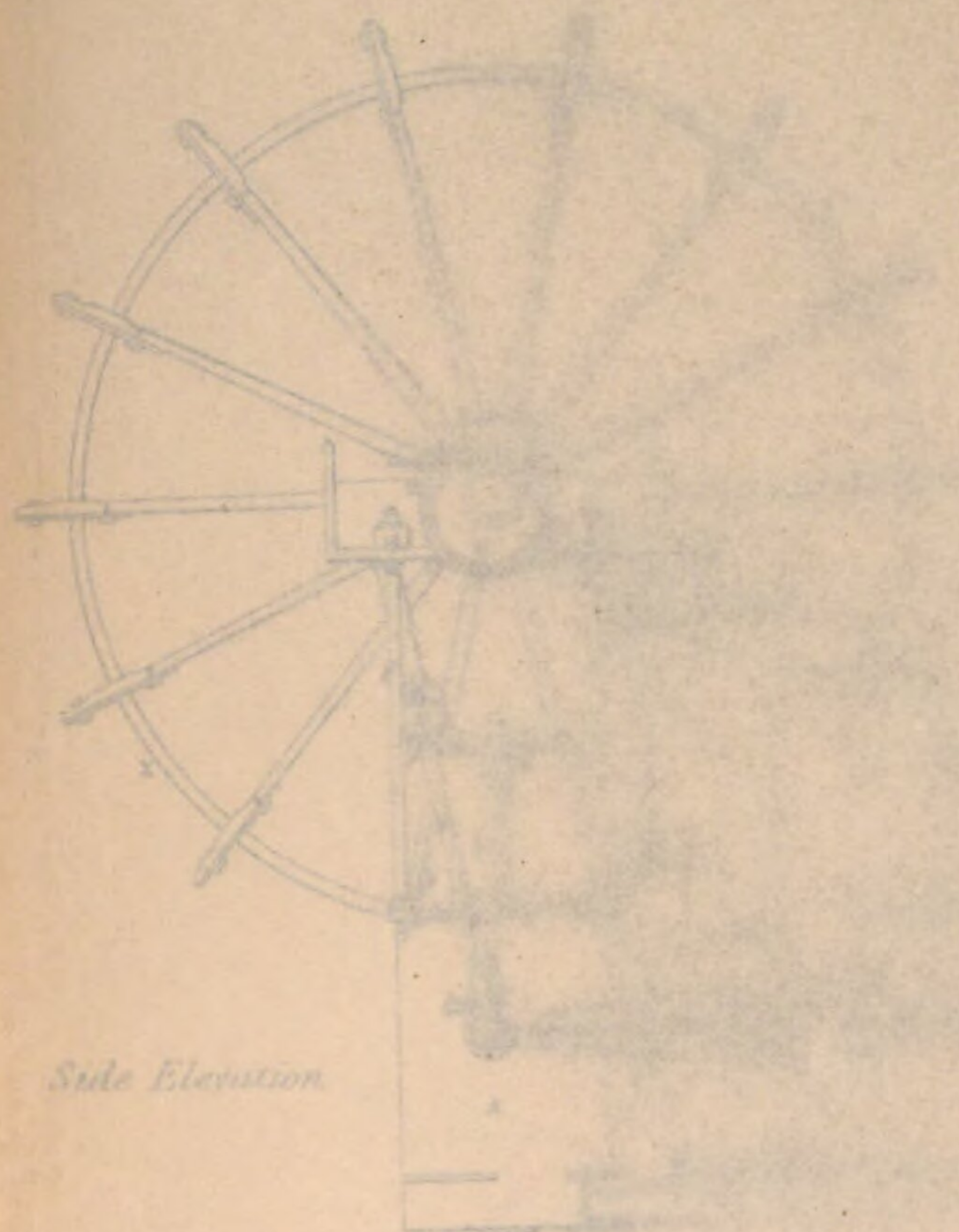


End Elevation.



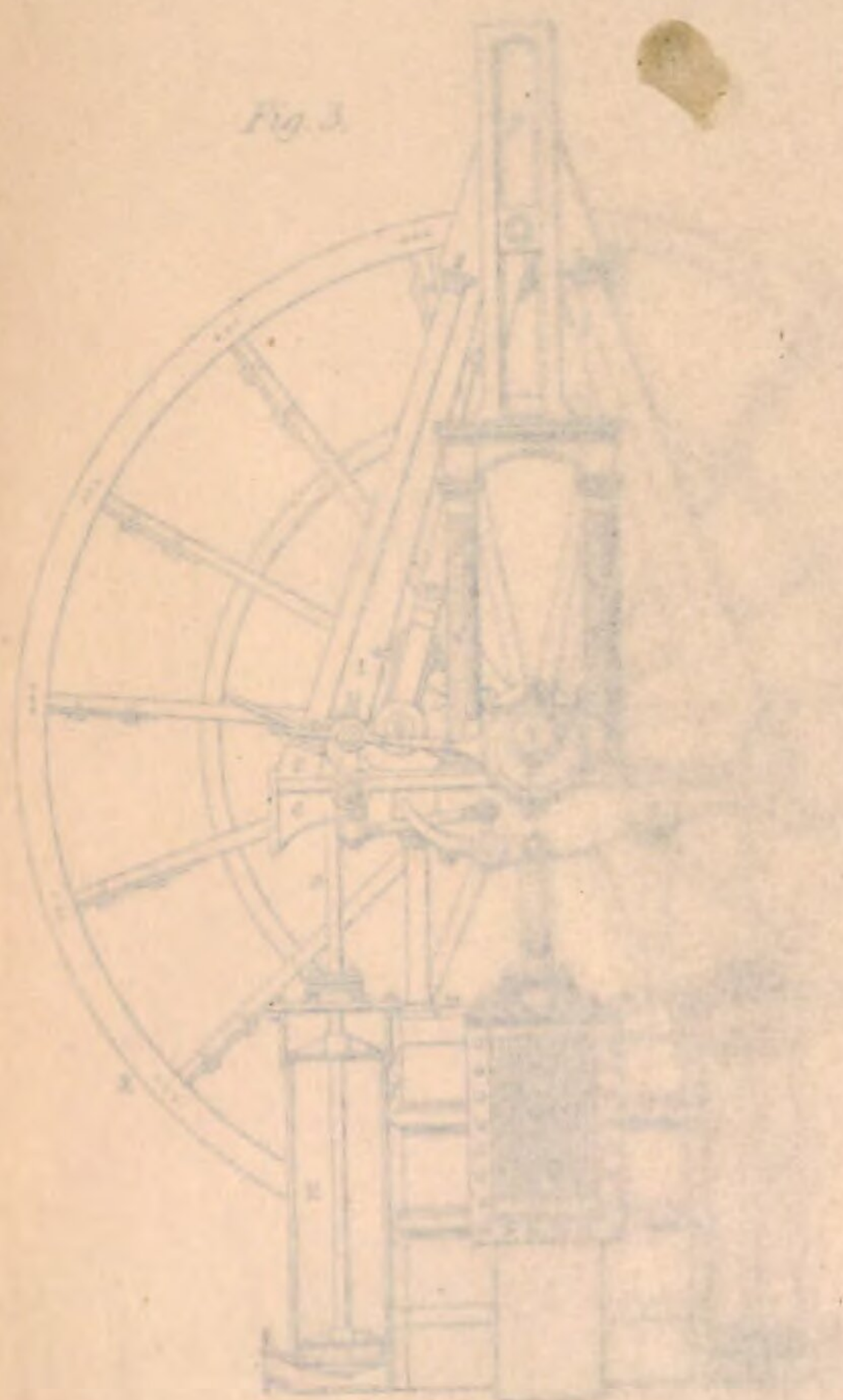
Side Elevation.

Fig. 2



Side Elevation

Fig. 3



Side Elevation

Diagram of a Steam Engine

Fig. 1

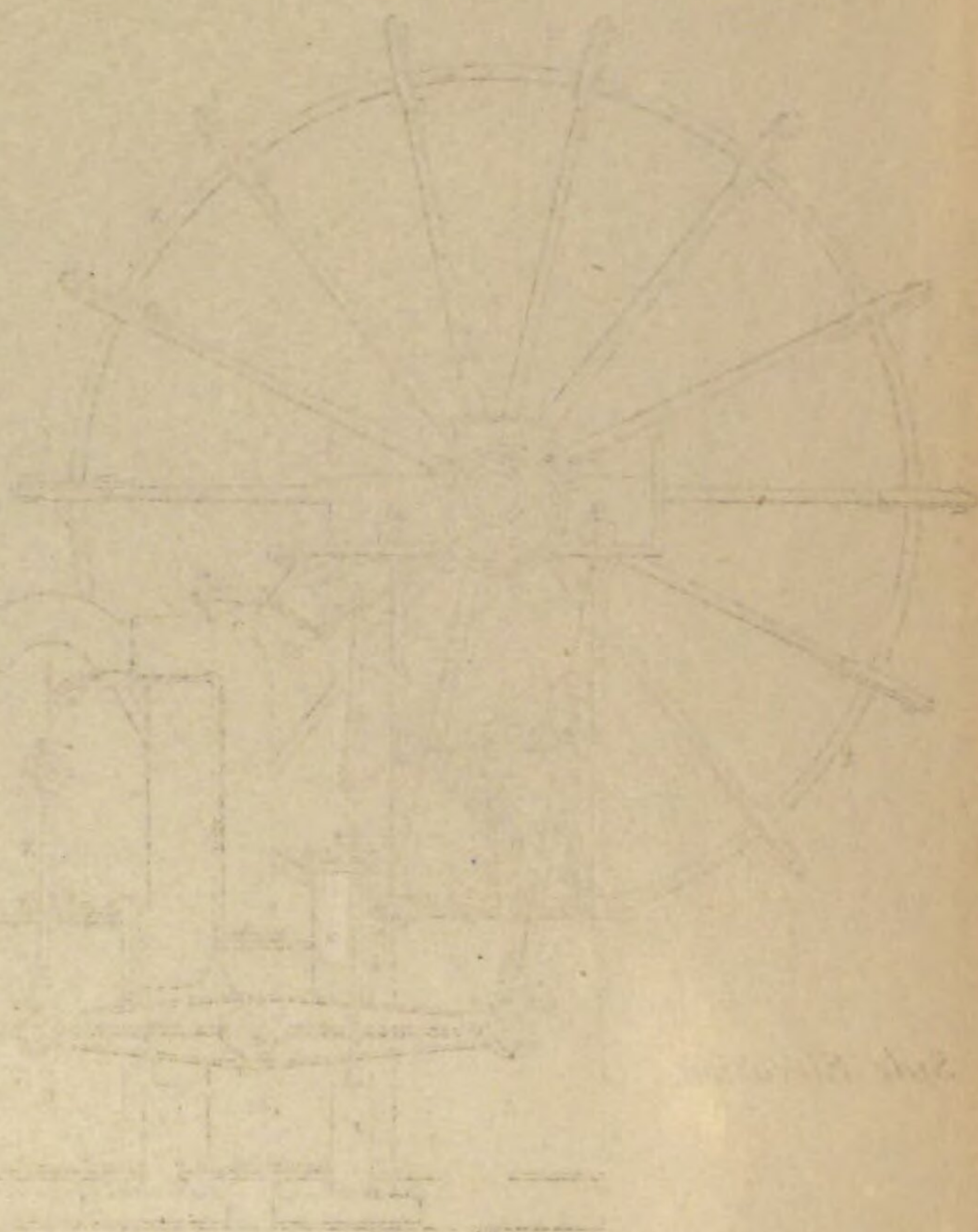
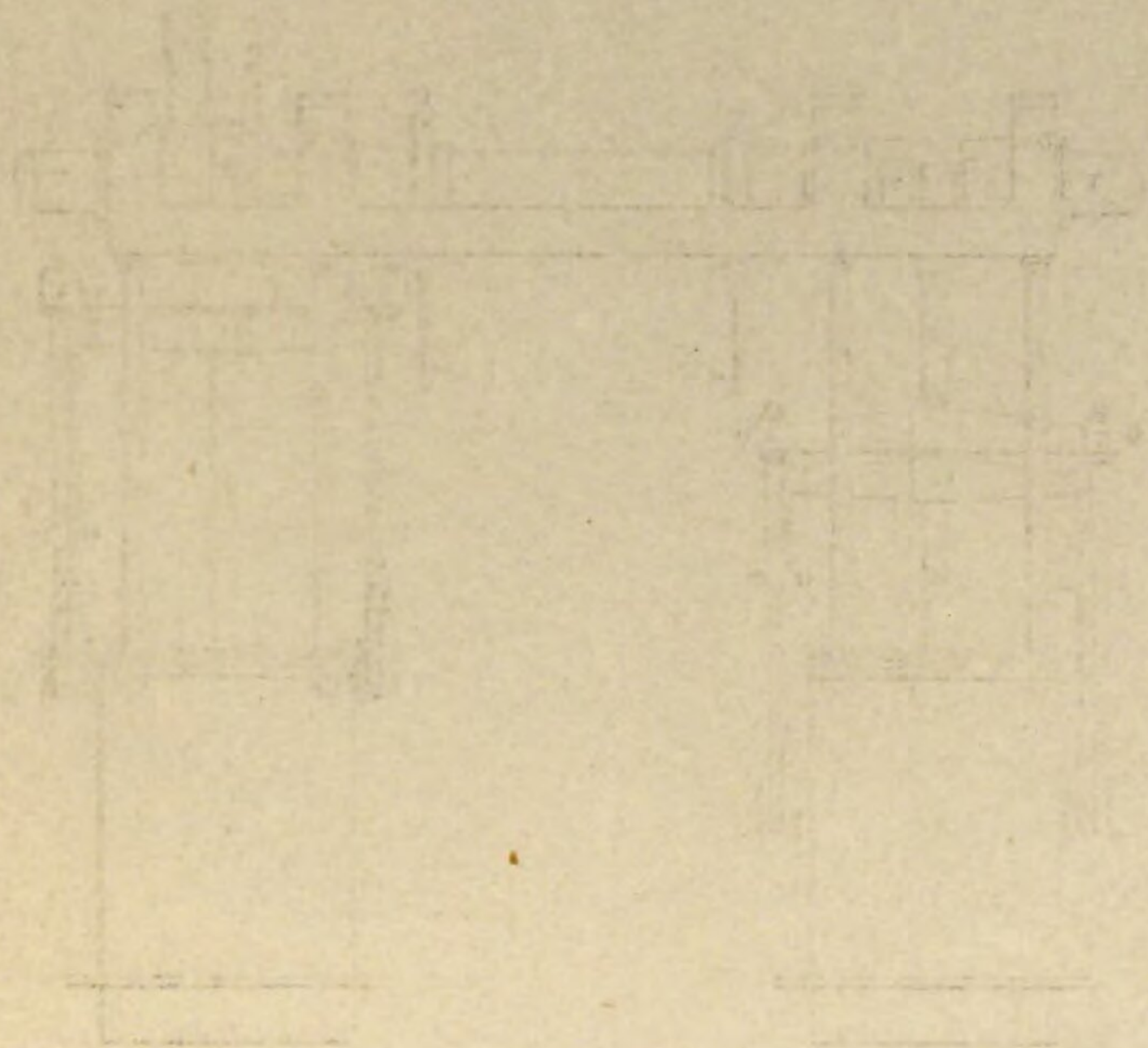


Fig. 2

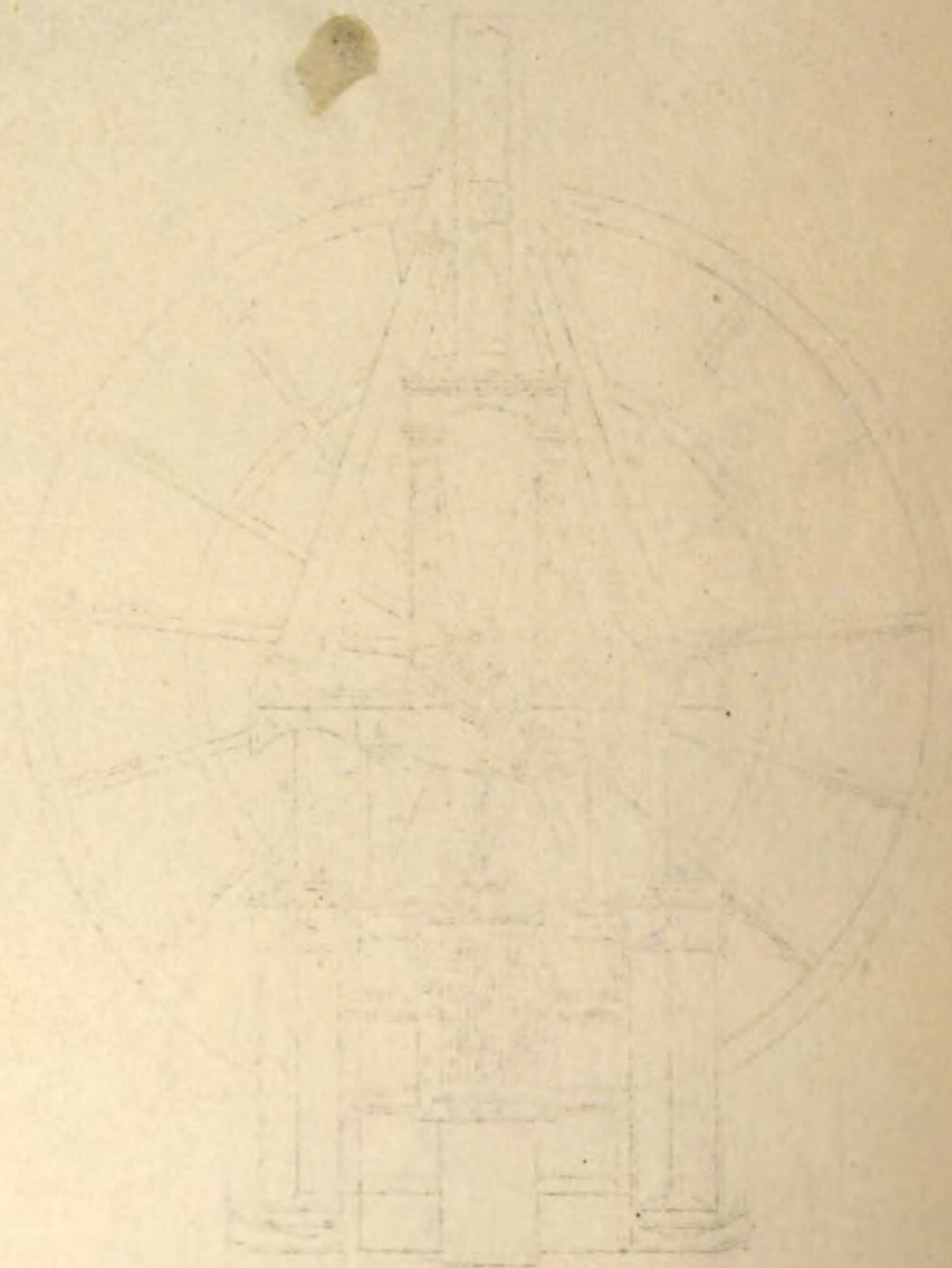
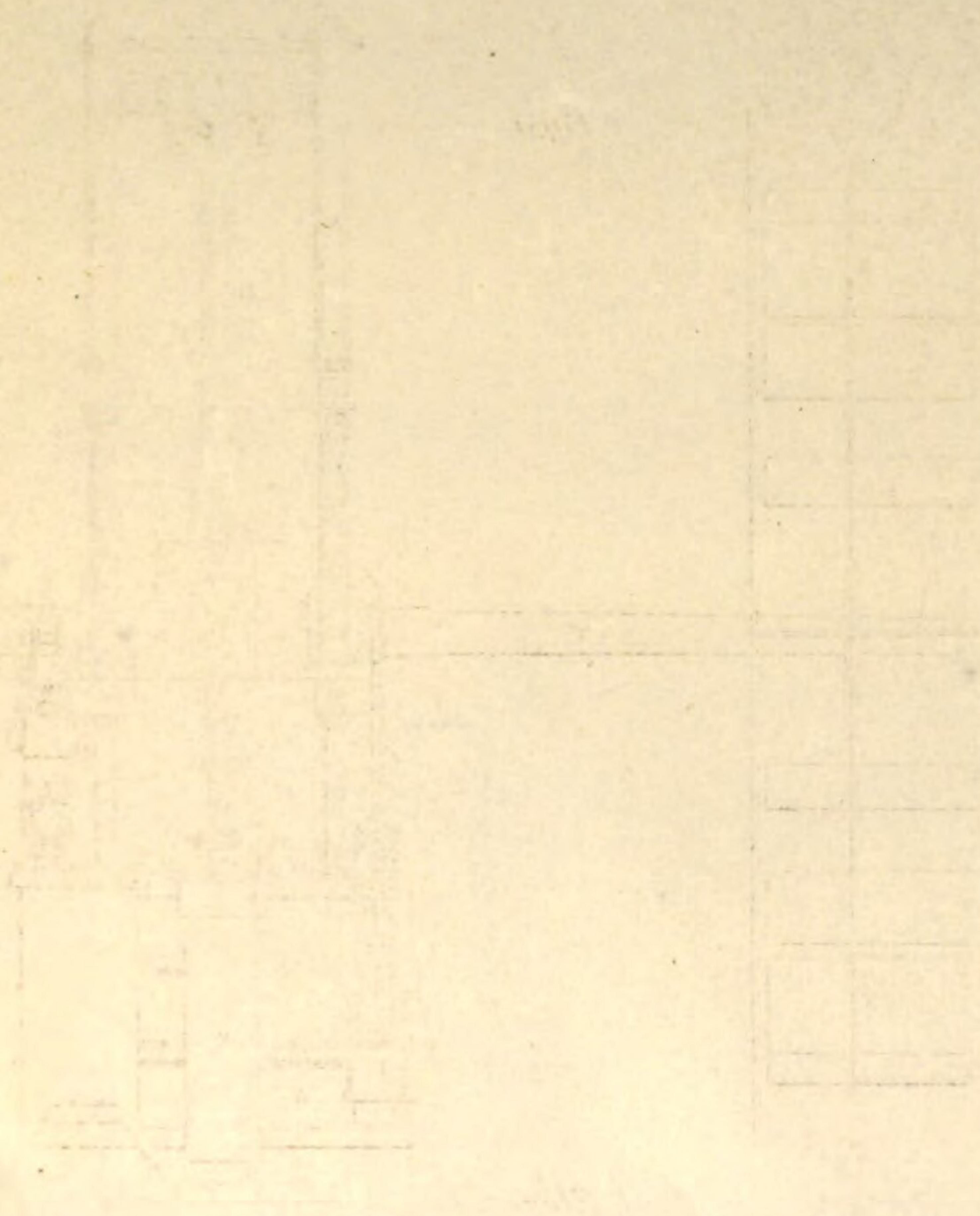
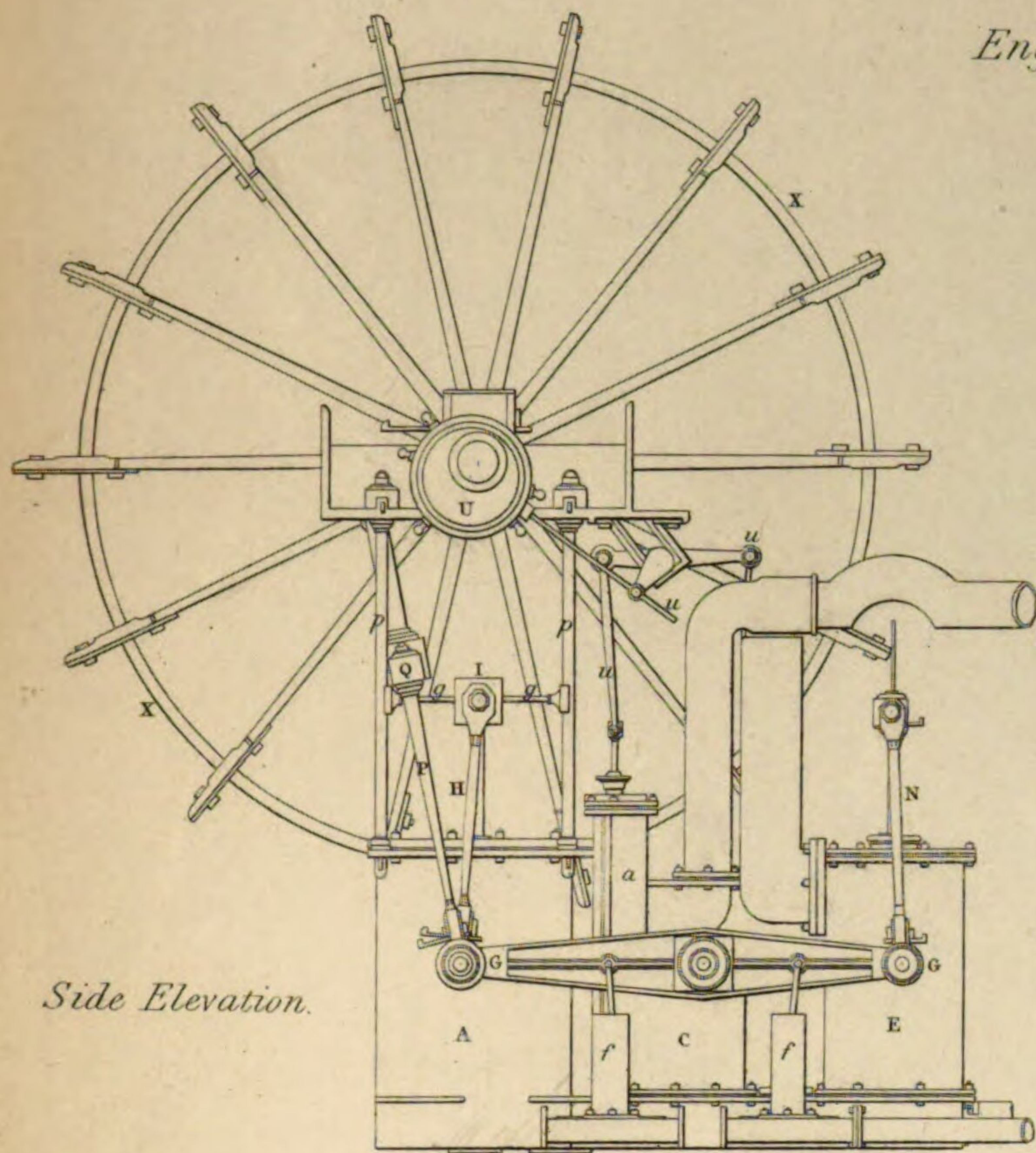


Fig. 3

Fig. 1.



Engines of direct connexion.

Fig. 2.

End Elevation.

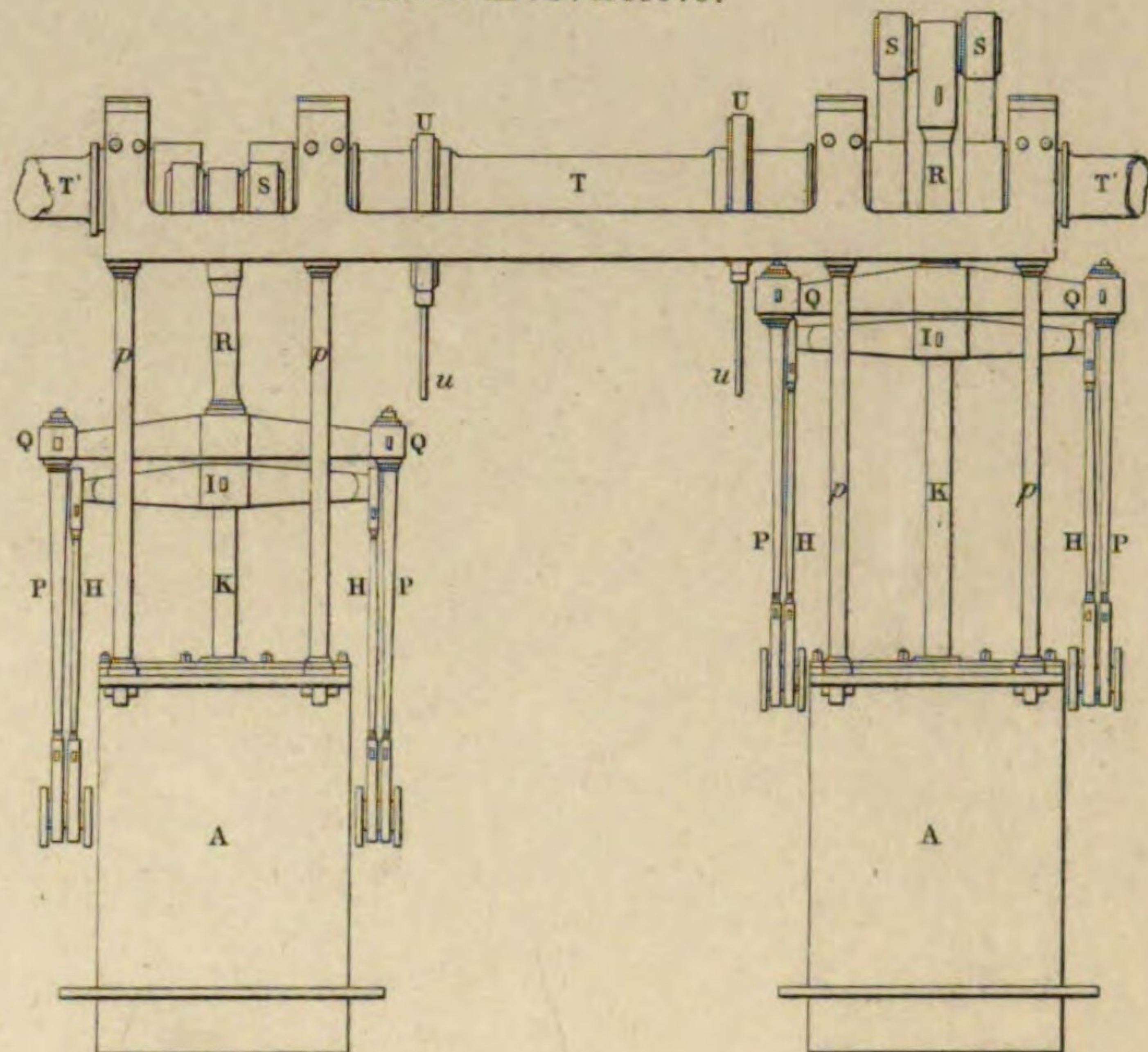
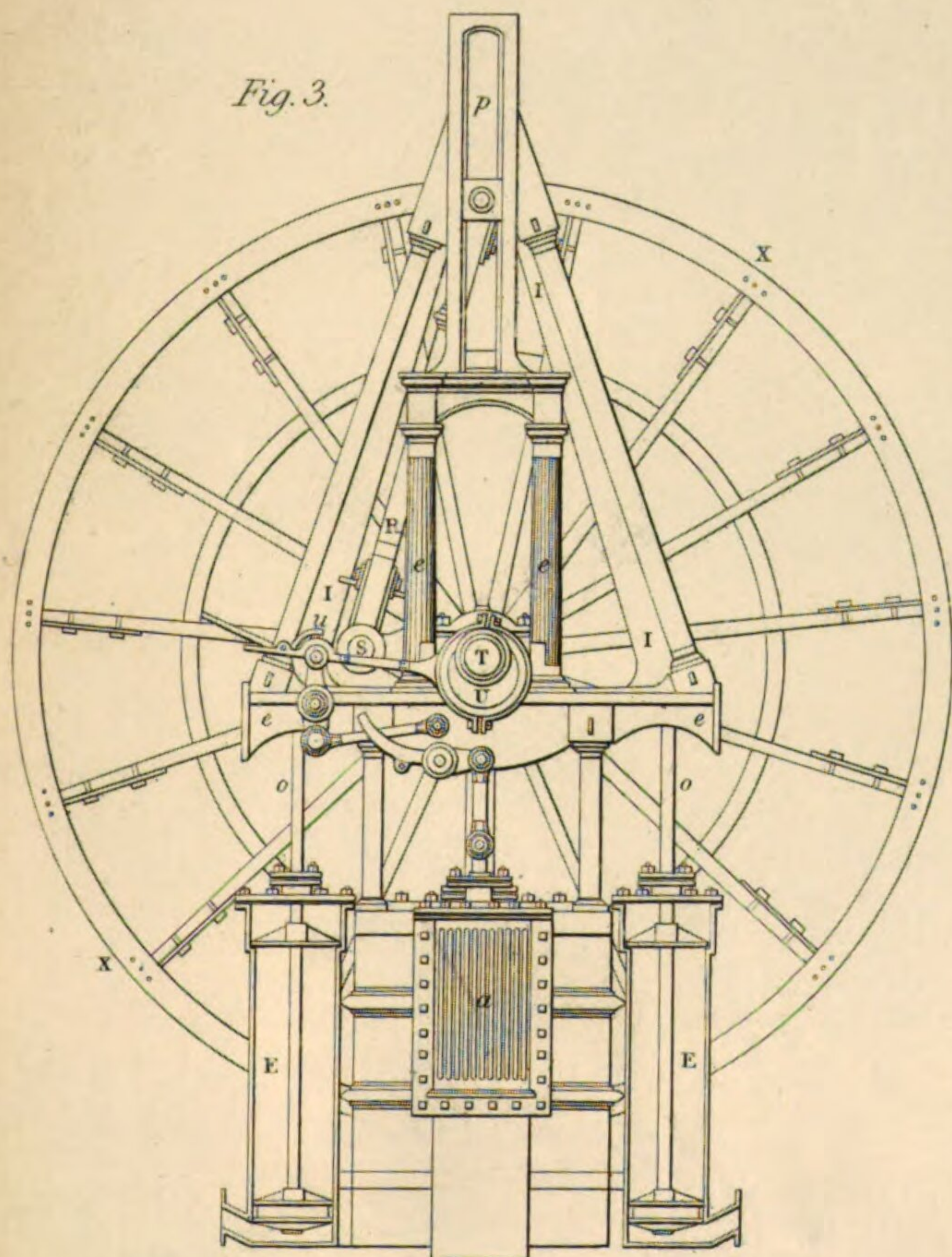
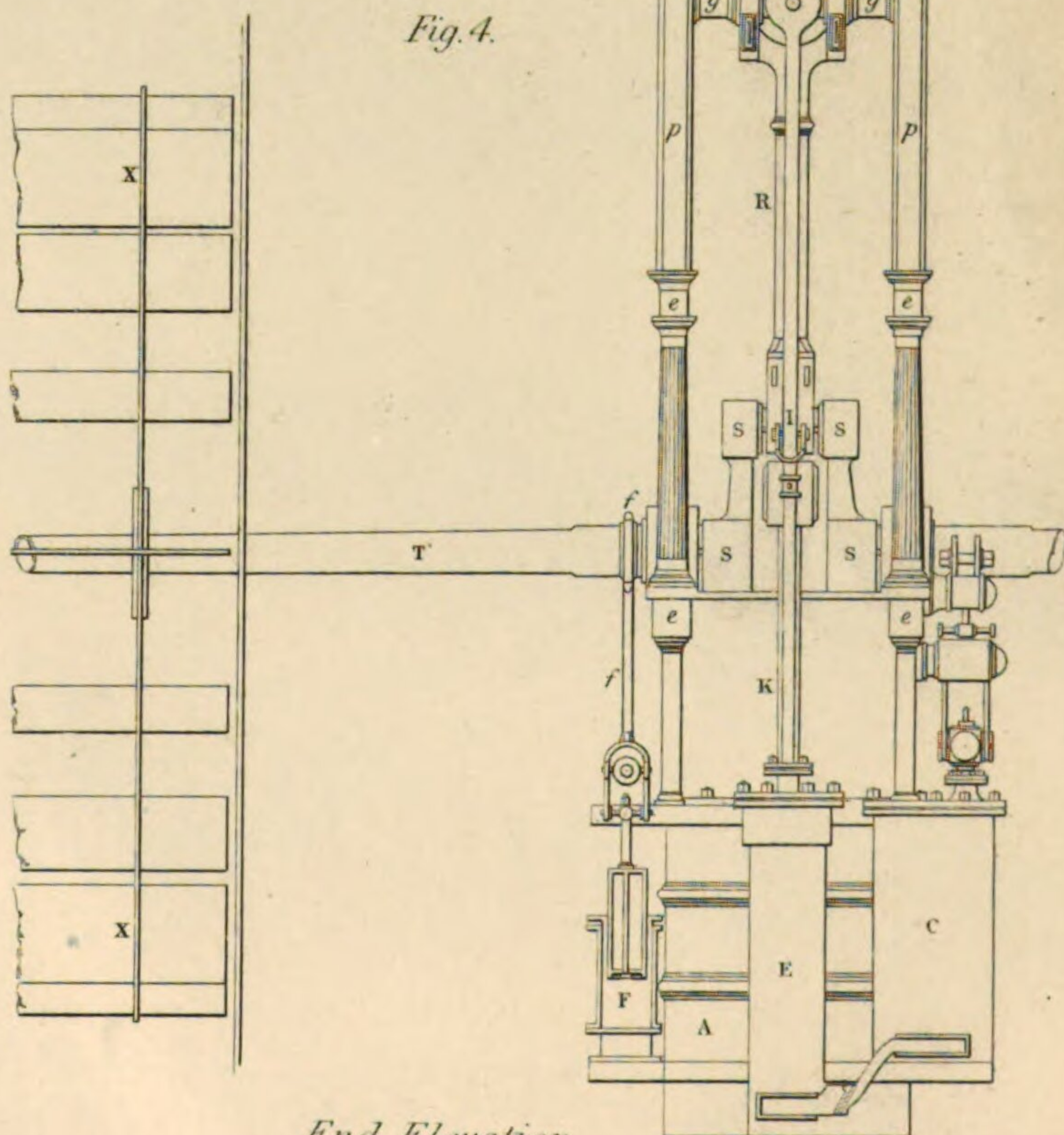


Fig. 3.



Side Elevation.

Fig. 4.



End Elevation.

大正元年十月十五日

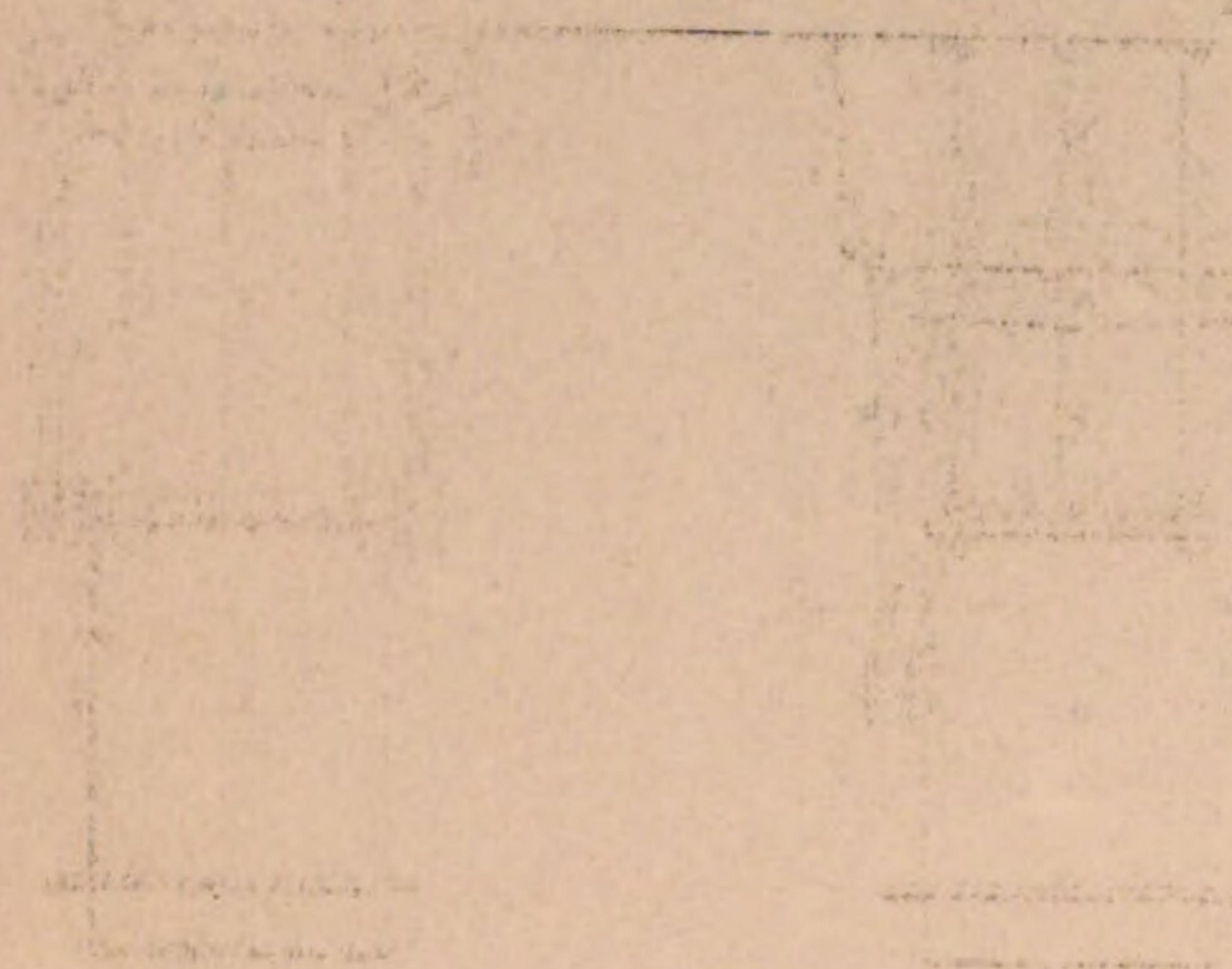
大正元年

大正元年十月十五日

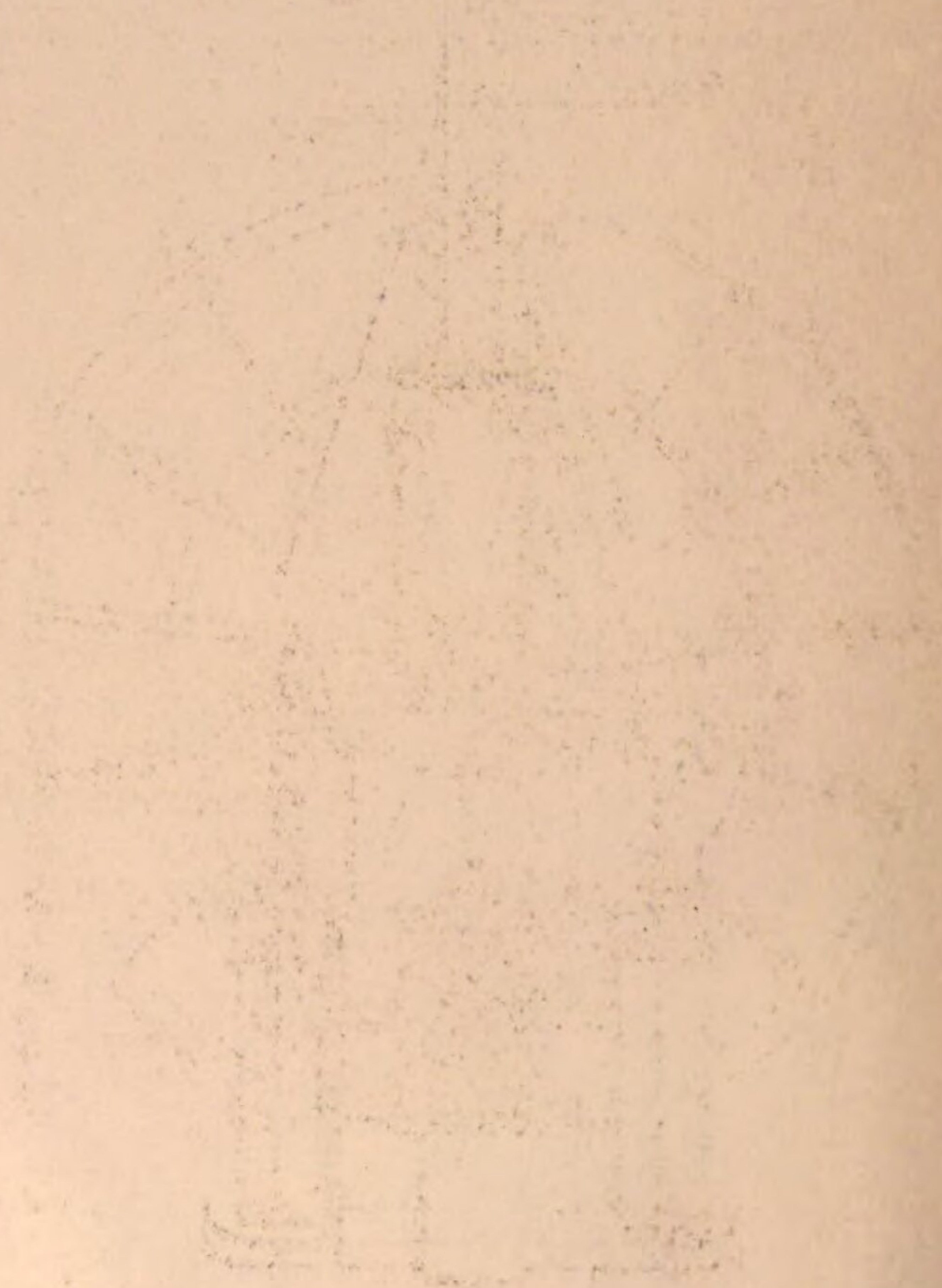
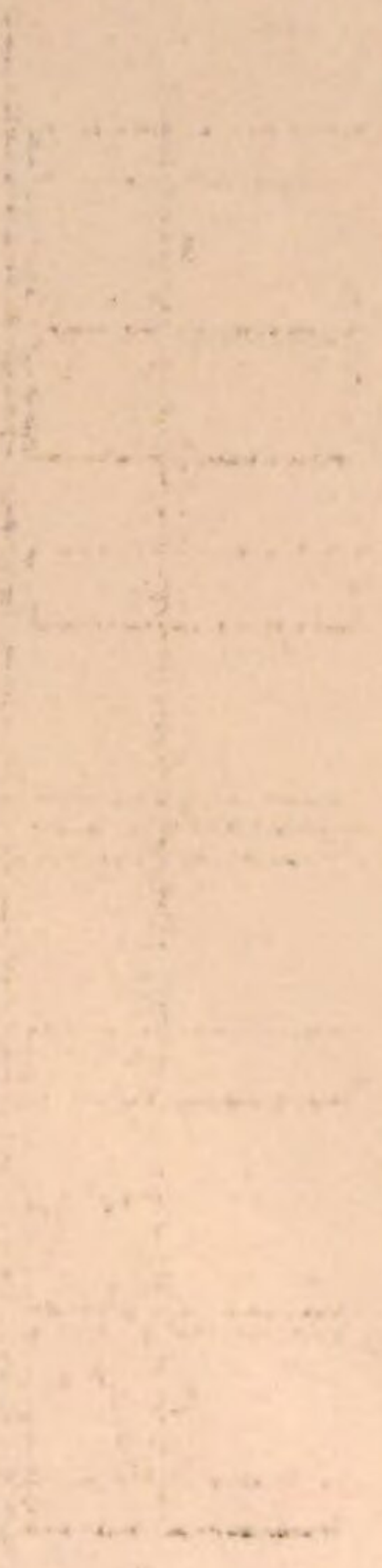
大正元年

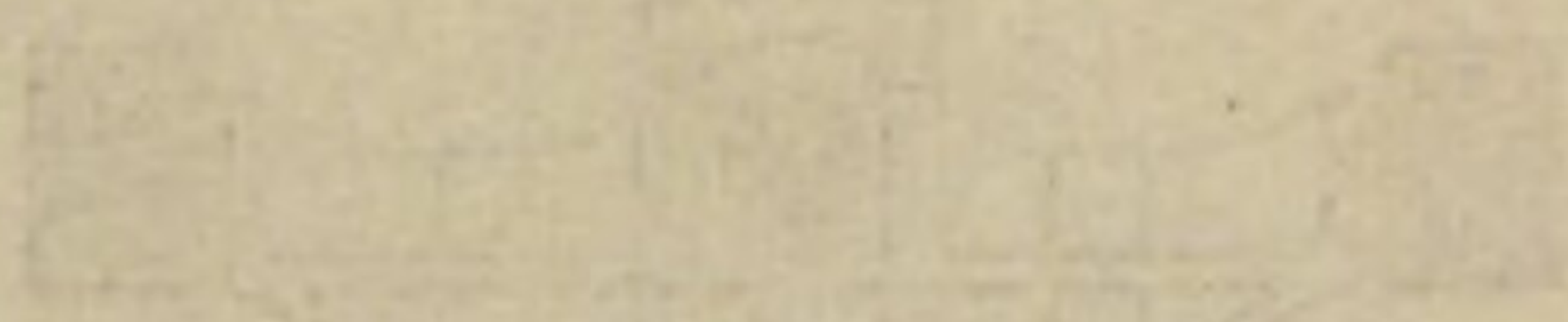
大正元年十月十五日

大正元年十月十五日



大正元年





Section of the Great Hall
showing the position of the
main entrance

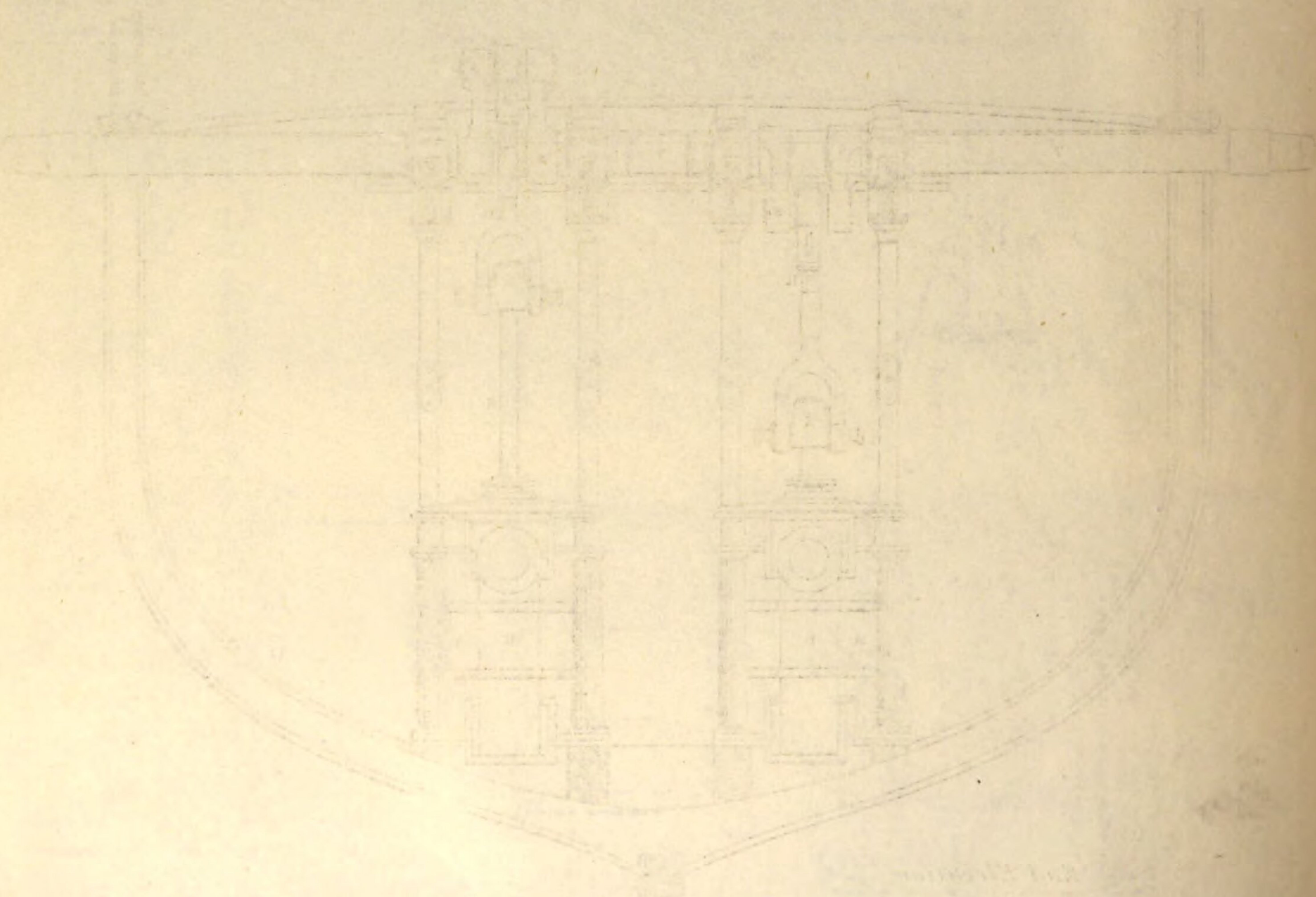
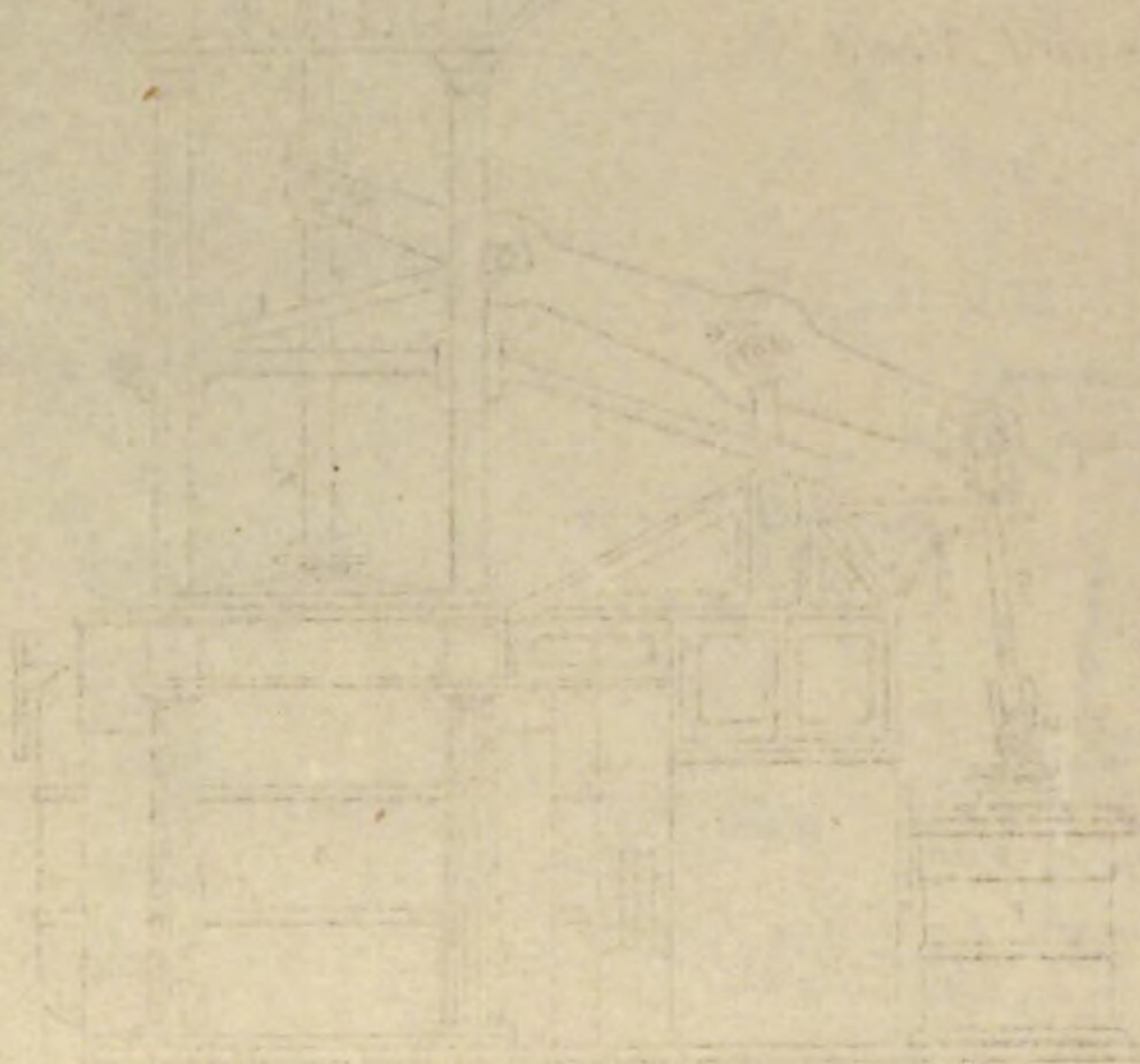
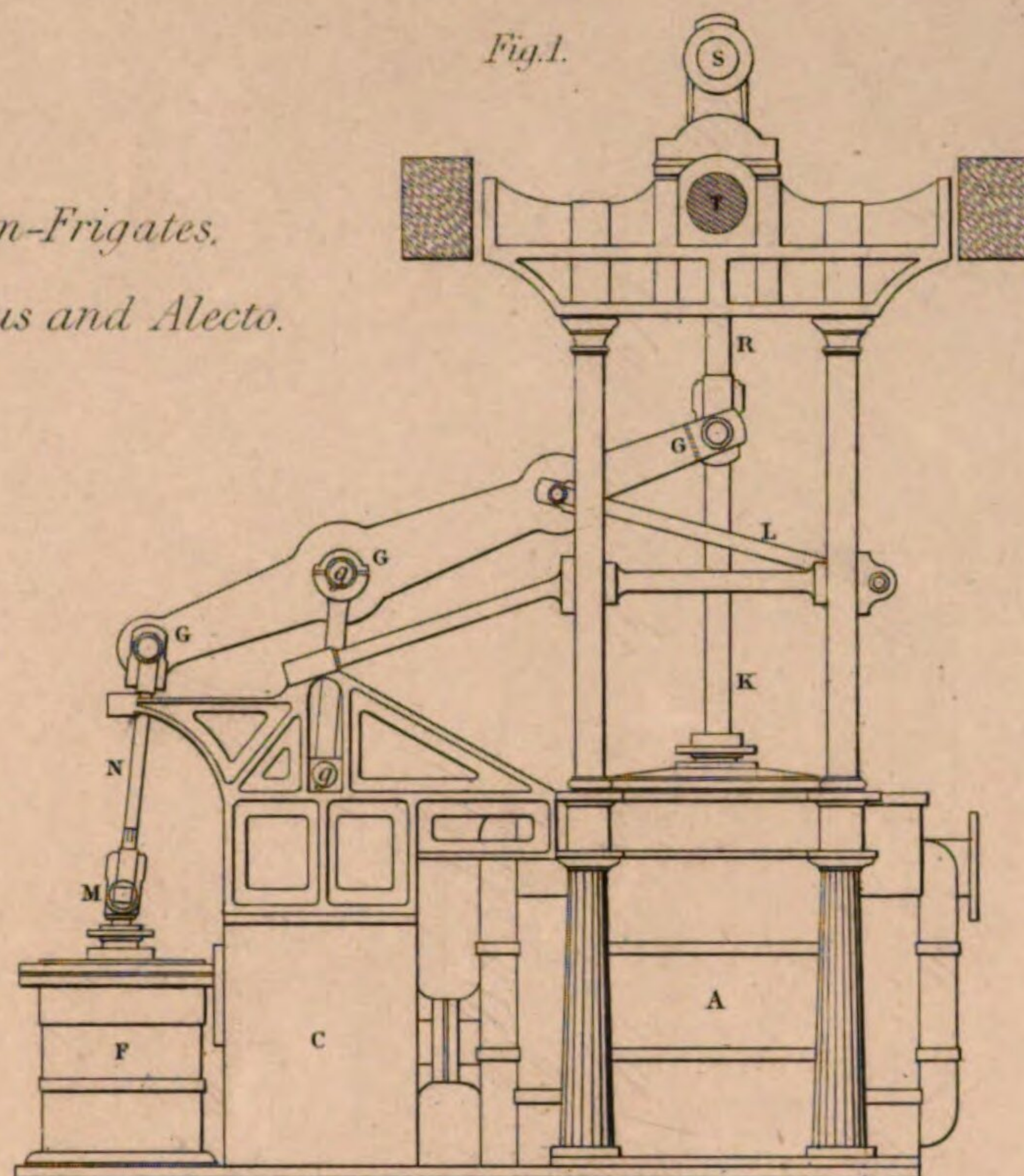


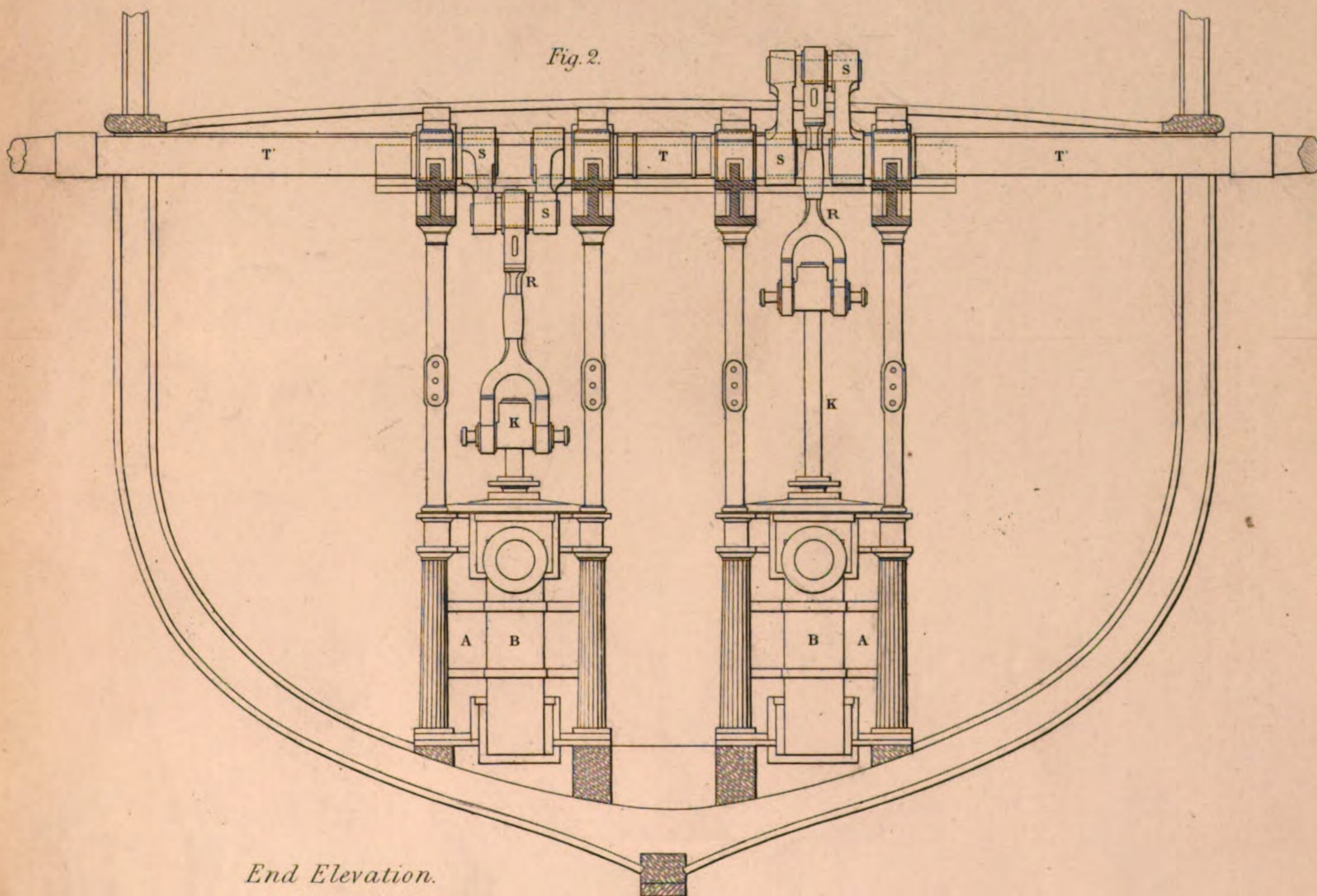
Fig. 1.

*Engines of H.M. Steam-Frigates,
Gorgon, Cyclops, Prometheus and Alecto.*



Side Elevation.

Fig. 2.



End Elevation.



THE ALPHABET

WITH THE DOUBLE & TRIPLE CONSONANTS

PREPOSITIONS AND TERMINATIONS

Letter or Char.	Arbitrary Abbreviations	Double Consonants	Triple Consonants	Prepositions and Terminations	Signification	Terminations	Class	Signification
a	a, an, at	ch	ack, ach	ab	about	able, ible	c	able
b	be, by, because	sh	shall, she	ad	ad, against	flat		
c	can, can't	th	that, the	an	an, and	flat	a	an, and
d	do, did	thr	there, then	ap	ap, at, upon	full		
e	ever, every, enough	ar	are, at, about	aw	away, without	france		
f	from, for	wh	what, when, where	ax	ax, at, with	ing	a	ing
g	God, give, go			ay	ay, at, with	ing	a	ing
h	he, had, his			ay	ay, at, with	ing	a	ing
i	I, eye, it			ay	ay, at, with	ing	a	ing
k	king, knew			ay	ay, at, with	ing	a	ing
l	Lord, will, all			ay	ay, at, with	ing	a	ing
m	me, my, most			ay	ay, at, with	ing	a	ing
n	and, in, nation			ay	ay, at, with	ing	a	ing
o	of, on, off			ay	ay, at, with	ing	a	ing
p	people, power			ay	ay, at, with	ing	a	ing
q	question, quantity			ay	ay, at, with	ing	a	ing
r	at, in, on			ay	ay, at, with	ing	a	ing
s	is, as, at			ay	ay, at, with	ing	a	ing
t	the, to, it			ay	ay, at, with	ing	a	ing
v	have, was			ay	ay, at, with	ing	a	ing
w	you, was, what			ay	ay, at, with	ing	a	ing
x	at, with			ay	ay, at, with	ing	a	ing
y	except, enough			ay	ay, at, with	ing	a	ing
z	in, your, for, from			ay	ay, at, with	ing	a	ing
	...			ay	ay, at, with	ing	a	ing

ABBREVIATING MARKS.

ARBITRARY MARKS.

as	at
by	only
of	nothing
in	where

1	Division	5
2	Divisible	2
3	Divide	5
4	Dividing	2

FIGURES.

1	2	3	4	5	6	7	8	9	0
10	11	12	13	14	15	16	17	18	19

A Comma	A Exclamation
A Colon	A Period
A Point of Interrogation	
A Point of Admiration	

THE LORD'S PRAYER.

Our Father who art in Heaven, hallowed be thy name. Thy Kingdom come. Thy will be done on earth as it is in Heaven. Give us this day our daily bread. And lead us not into temptation, but deliver us from the evil one. For thine is the Kingdom, the power, and the glory, forever. Amen.

THE RECORD

OF THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PRINTED BY THE CITY OF ST. LOUIS, MO.

FOR THE YEAR 1870.

PREPOSITIONS AND TERMINATIONS.

Letters. Char. Arbitrary Abbreviations.			D ^{ble} Cons. &c. Char. Arb ^{try} Abbreviations.			Prepositions. Char. Exam. Signification.			Terminations. Char. Exam. Signification.				
a	'	a, an, <u>above</u>	ch	\	each, such.	abs, obs	c	c	abstain.	able ible	c	}	stable.
b	c	be, by, because.	sh	b	shall, she.	anti, ante.	'	ḡ	antidote.	flict	c	u	conflict.
c	v	~	th	f	that, they.	anta	v	v	counterfeit.	flect			
d	o	do, did.	thr	q	therefore.	contr-i-a			counter	full			
e	,	ever, every, <u>middle</u>	str	q	strive, strong.	contro	o	o	discompose.	ference	o	d	thing.
f	q	from, if.	wh	l	who, which.	counter			hyp-o-cr	ing			
g j	σ	God, give, gives.	VOWELS PLACES.			dis-in-com			magn-i-a	ings			
h	f	he, had, his.				hyp-o-cr	f	fm	hypocrite.	tion	o	e	petition.
i	,	I, eye, <u>below</u>	a.	e.	i.	o.	u.	y.	magn-i-a	cion			
k	\	king, know.	b	'c'	'c'	'c'	'c'	'c'	multi	sian			
l	/	Lord, will, all.	d	'c'	'c'	'c'	'c'	'c'	omni	cian	o	e	thesis.
m	u	me, my, most.	f	'c'	'c'	'c'	'c'	'c'	int-er-ro	tion &c.			
n	u	and, in, nature.	g	'c'	'c'	'c'	'c'	'c'	enter	tions &c.			
o	.	O, oh, owe, <u>above</u>	h	'c'	'c'	'c'	'c'	'c'	post	siss ces	n	l	harmless.
p	p	people, peace.	k	'c'	'c'	'c'	'c'	'c'	preter	sys sus			
q	e	question, quantity.	lr	'c'	'c'	'c'	'c'	'c'	recon	tious			
r	t	or, are.	m	'c'	'c'	'c'	'c'	'c'	recom	cious &c.	o	e	indictment.
s	-	is, us, soon.	n	'c'	'c'	'c'	'c'	'c'	satis	less			
t	l	the, to, it.	p	'c'	'c'	'c'	'c'	'c'	super	ment			
v	o	have, save.	q	'c'	'c'	'c'	'c'	'c'	circum	self	o	e	himself.
u	.	you, view, <u>middle</u>	s	'c'	'c'	'c'	'c'	'c'	trans	tract			
w	l	we, with.	t	'c'	'c'	'c'	'c'	'c'	ext-er-in	strict			
x	d	except, example.	v	'c'	'c'	'c'	'c'	'c'	extra	ward	o	e	forward.
y	.	ye, your, yes, <u>below</u>	w	'c'	'c'	'c'	'c'	'c'					
z	-	~	x	'c'	'c'	'c'	'c'	'c'					



The Encyclopaedia Britannica, or Dictionary of Arts, Sciences, and General
Literature

Bd.: 20,2

Edinburgh (1842)

4 Enc. 7 c-20,2

urn:nbn:de:bvb:12-bsb10487022-4